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MEASUREMENT OF FOG OIL PENETRATION INTO MODEL UNDERGROUND BURROW AND HOLLOW TREE NEST CAVITIES

Mark A. Guelta

RESEARCH AND TECHNOLOGY DIRECTORATE

Harold E. Balbach

CONSTRUCTION ENGINEERING RESEARCH LABORATORY
Champaign, IL 61826-9005

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The Gopher tortoise (*Gopherus polyhemus*) and the Indiana Bat (*Myotis sodalist*) are species found on many military installations. The Indiana bat is endangered throughout its range, and the Gopher tortoise is threatened in its westernmost distributions and at risk everywhere else. On installations where troop readiness training is conducted, an important component of realistic troop readiness training is the generation of obscurant material and the conduct of maneuvers under obscurant cover. Fog oil (FO) has long been deployed for visual obscuration training, and the effects of such obscurants on these species are unknown. As a preliminary step prior to instituting toxicological studies, a laboratory simulation was performed on the capability of FO to penetrate the living space of these species: the tortoise burrow and the hollow-tree location of a bat maternity colony. The FO smoke did not enter the simulated tortoise burrow in significant concentrations, but the smoke concentrations in the simulated tree cavity approached ambient levels under some test conditions. This suggests that tortoise burrows do not need to be studied in-situ, and that the tortoise may be considered protected while in the burrow. Bat maternal colony sites, however, should not be considered protected from smoke entry to any significant degree.

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PREFACE

The work described in this report was authorized under Sales Order No. 3RE31-1 (ER33), Ecological Processes Branch, U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory. This work was started in November 2003 and completed in August 2004.

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CONTENTS

FIGURES

TABLES

MEASUREMENT OF FOG OIL PENETRATION INTO MODEL UNDERGROUND BURROW AND HOLLOW TREE NEST CAVITIES

1. INTRODUCTION

Concerns over potential effects to Threatened and Endangered Species (T&E) from activities at U.S. Army training sites has sparked much debate over field study and closure or limitations of activities on Army testing and training sites. Range managers must often balance the requirements of troop training exercises and equipment testing against the need to protect individual and/or populations of T&E species. The use of battlefield smokes for marking and screening represent a challenge in that they not only affect the immediate area of application, but also any areas down wind of the test site.

Testing and training sites can encompass large areas of relatively undisturbed open range and wooded areas. These sites have become valuable for existing and displaced animal species including populations of T&E species. Therefore, the protection of these T&E species has fallen more under the stewardship of the U.S. Army than any other service or public group. The ability to manage and make decisions regarding training and testing requirements versus T&E species stewardship requires insight into species habitat requirements, lifecycle, the seasonality of testing and training, and effect of testing, if any, on the species of concern. A preliminary assessment on the potential impact of Fog Oil (FO) Smoke on selected T&E Species has been conducted.[1] Part of their findings and recommendations included the testing of certain assumptions regarding the protection a nest cavity or underground burrow may afford its occupants. Specifically mentioned were the nests of the Red-Cockaded Woodpecker (RCW), Indiana Bat (Myotis *sodalis*) and Gopher Tortoise (Gopherus *polyphemus*). Two studies have since been performed on the penetration of FO into RCW nest cavities.[2,3] Data for Indiana Bat and Gopher Tortoise exposure to FO in their nesting sites is still limited.

The Gopher Tortoise has a natural range in southeast U.S. from southern Georgia, west to southern Mississippi, and south throughout Florida. The Gopher Tortoise digs underground burrows in softer sandy soils that can extend up to 30 ft. in length. Other ground dwelling animals also frequent these burrows, which have been believed to provide the inhabitants with protection from exposure to the smoke used at these test sites. The general lack of test data to support the idea of protection provided by an underground burrow has led to the proposed testing of underground burrows. The greatest threat to the Gopher Tortoise is loss of habitat. The Gopher Tortoise is therefore frequently found on government lands, including Army testing and training sites. Wilson and Mushinsky[4] have reported active Gopher Tortoise burrows on 19 testing and training sites throughout southeastern U.S. The Gopher Tortoise and many other vertebrate species make use of the burrows for shelter from temperature extremes and predation. The Gopher Tortoise excavates burrows that are generally 5 m in length and of a diameter to allow them to turn around. A single tortoise could use several burrows simultaneously over its normal range.

The Indiana Bat domicile range extends from the Ozark Plateau in Oklahoma, north to Iowa and southwestern Wisconsin, east to New Hampshire and south to portions of Georgia and Alabama.[5] The bats migrate seasonally from their summer habitat in northern closed canopy riparian forests to their winter hibernation areas in southern limestone caves and abandoned mineshafts. Summer roosts are generally loose or heavily barked trees that provide solar shelter. Maternity roosts may be large standing dead trees that are frequently found in the area of permanent streams or floodplain forests. Snags and broken or hollowed trunks are also used by the bats for roosting, though to a lesser degree. Single male bats or maternity colonies may use several roosting sites or move frequently between primary and alternate roosts depending on environmental conditions or disturbance.

Generally the collection of field data can prove challenging and costly. Site characteristics, uncooperative weather, and the logistics of conducting fieldwork often greatly increase the costs and decrease the quality of the data collected. The potential costs of conducting field tests can place desirable programs on a back burner until the impact to range use or testing has been realized. Alternatives are initial testing conducted under the more controlled conditions of a laboratory or an engineered study using models that closely imitate field conditions.

This study is designed to gather the initial data to assess the potential penetration of the large area screening smoke "FO" into a model Gopher Tortoise burrow and a hollow standing tree cavity. During this study, models were constructed to closely approximate the geometry of burrows and cavities observed in the field. Fog Oil smoke was generated at concentrations that may be used in field exercises and presented to the burrow entrance at wind speeds and orientations representing field conditions. These conditions included 3-wind speeds from 4 to 12 mph, wind orientations of 0°, 90° and 180° and concentrations from 50 to 300 mg/m^3.

2. METHODS

2.1 Gopher Tortoise Burrow.

The Gopher Tortoise burrow was constructed using corrugated 8-in. diameter plastic drainpipe and 8-in. diameter dryer vent hose (Figures 1 and 2). The opening to the model burrow was fabricated using ¼-in. plywood, expanded metal screening and plaster of Paris. The burrow opening was designed to simulate the depression made by a tortoise at the entrance, which gradually sloped to approximately 8-in., below grade. The top of the burrow entrance was slightly below grade, with a mound of simulated dirt slightly above grade.

The entrance to the model burrow was constructed on a moveable platform that fit into a wind tunnel test section. The platform was movable to effect FO challenge orientation. The model burrow was 5 m in length. Aerosol sensors were placed just outside the entrance and 1, 3, and 5 m below the inside opening of the burrow for challenge FO concentration measurement.

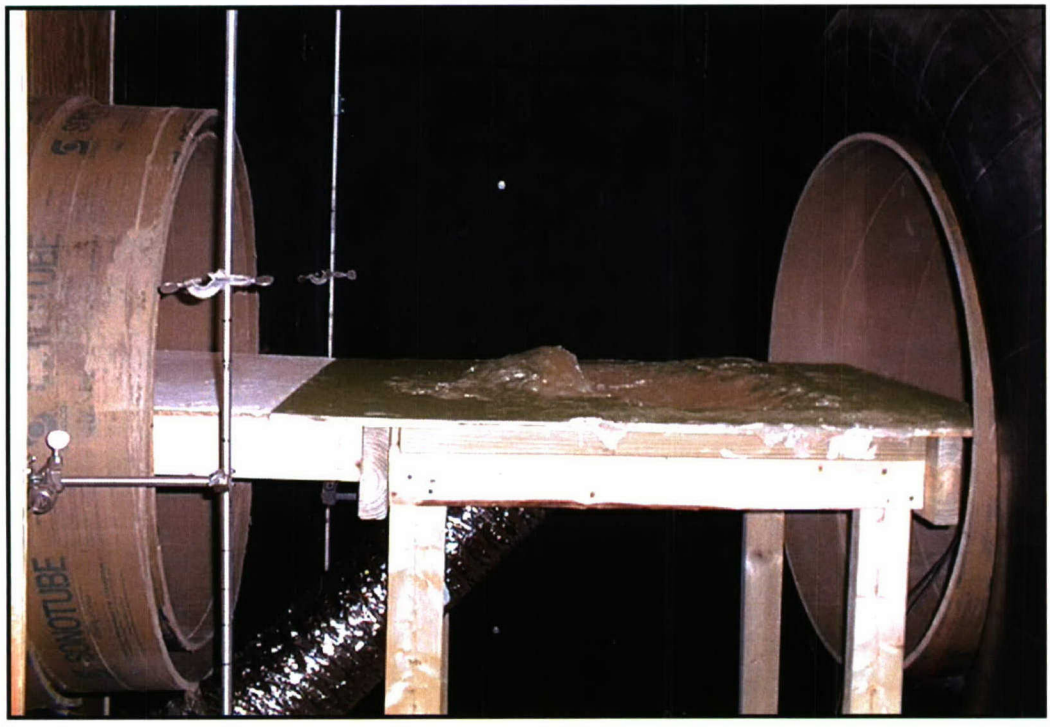

Figure 1. Model Gopher Tortoise Burrow Placed in Wind Tunnel Test Section with Entrance Oriented 180° to Wind Direction.

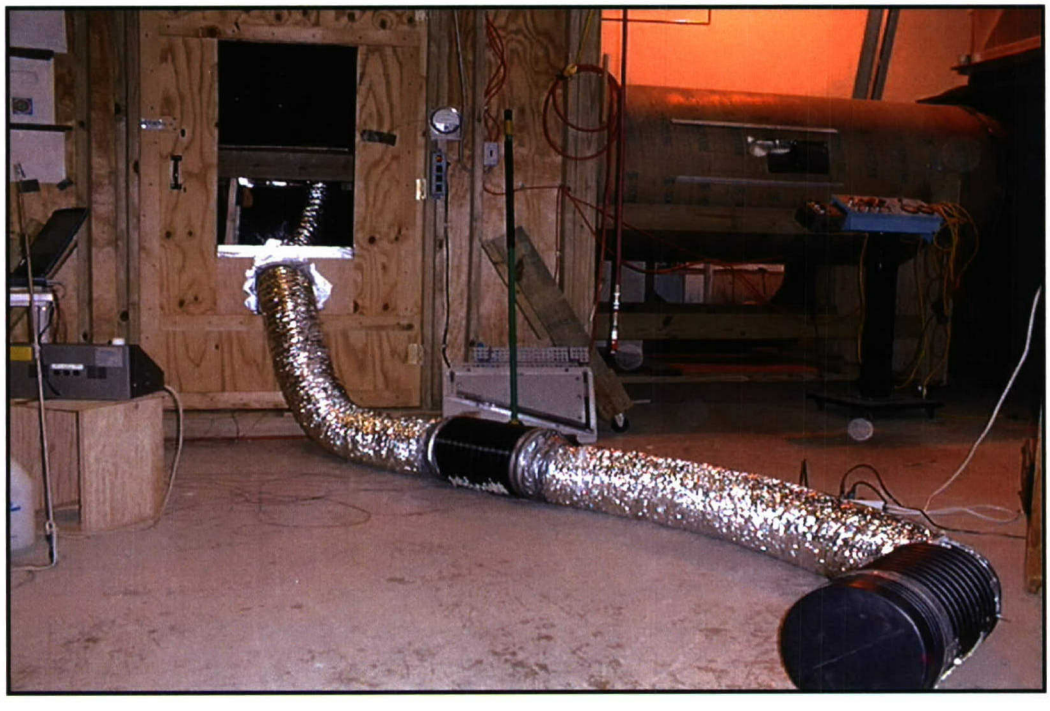

Figure 2. Model Gopher Tortoise Burrow Extended through Door of Test Section with Entrance Facing 90° to Wind Direction.

2.2 Tree Trunk Nest Cavity.

The hollow tree trunk model, simulating the Indiana Bat nests, was constructed from an 8-in. diameter corrugated plastic drainpipe (Figures 3 and 4). Aerosol sensors were mounted at the entrance to the model and at each end of the 88-in. long pipe. The cavity wall was made to simulate a 1 ½-in. thick trunk by encasing the corrugated pipe in a 12-in. (nominal) fiber tube. The inner cavity of the model was held in place by expanding foam and screws. Mounting screw heads, tube joints, and aerosol sensor access holes were sealed with expanding foam, silicon caulk, and duct tape.

Figure 3. Inner Section of the Tree Trunk Cavity Constructed of 8-in. Drainpipe.

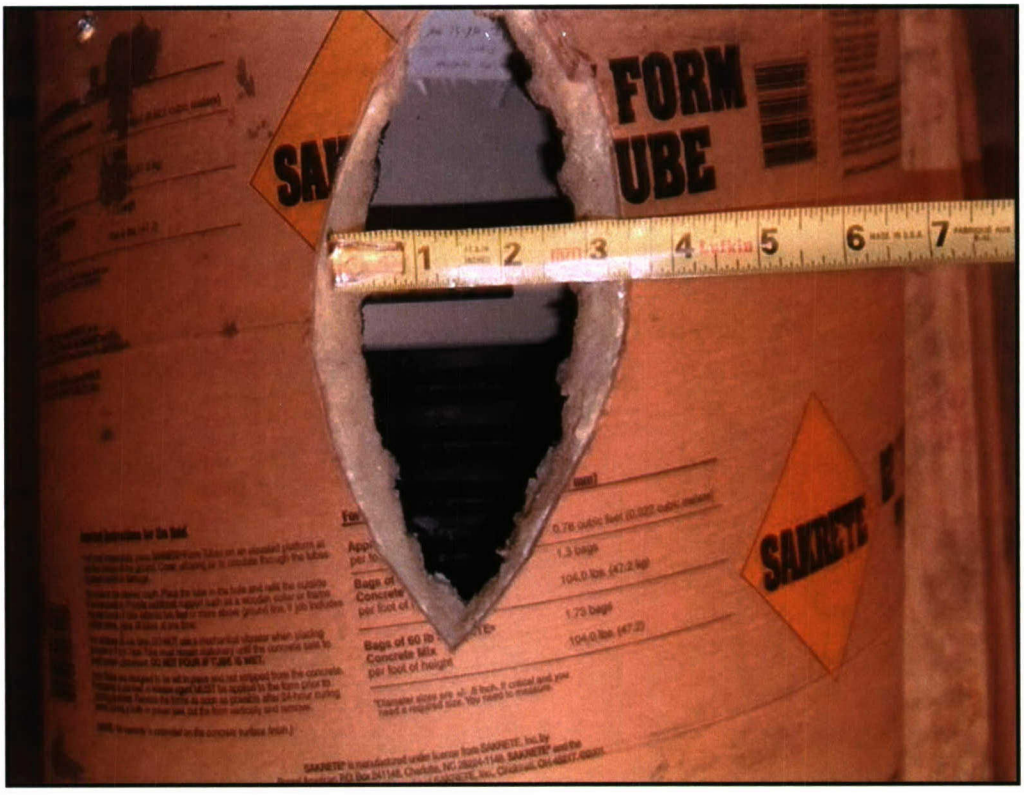

Figure 4. Entrance to the Nest Cavity Cut through the Outer Shell of the Tree Trunk, the Filler Foam, and the Hollow Plastic Pipe.

2.3 Generation of Fog Oil.

Fog oil was generated using a pair of Small Scale Smoke Generators (S3-G). An S3-G is a gas powered electric generator with a modified exhaust system (Figure 5). This type of small system is used for FO generation and its portable power is used to operate FO detection equipment, pumps, data loggers, and computer systems.

The modified exhaust/vaporization chamber is comprised of a 1 ½-in. diameter by 24-in. long galvanized pipe. Ports at the end of the exhaust allow injection of FO and engine exhaust. The hot exhaust from the S3-G engine vaporizes the liquid FO and directs it into the wind tunnel inlet. High temperature heat tape assists in the vaporization of the FO and keeps the exhaust gas in the vaporization chamber above 400 °C. Fog Oil is pumped from a holding reservoir and injected into the vaporization chamber by a peristaltic pump. The variable speed of the pump allows control of the amount of FO generated and challenges FO concentration at the burrow opening.

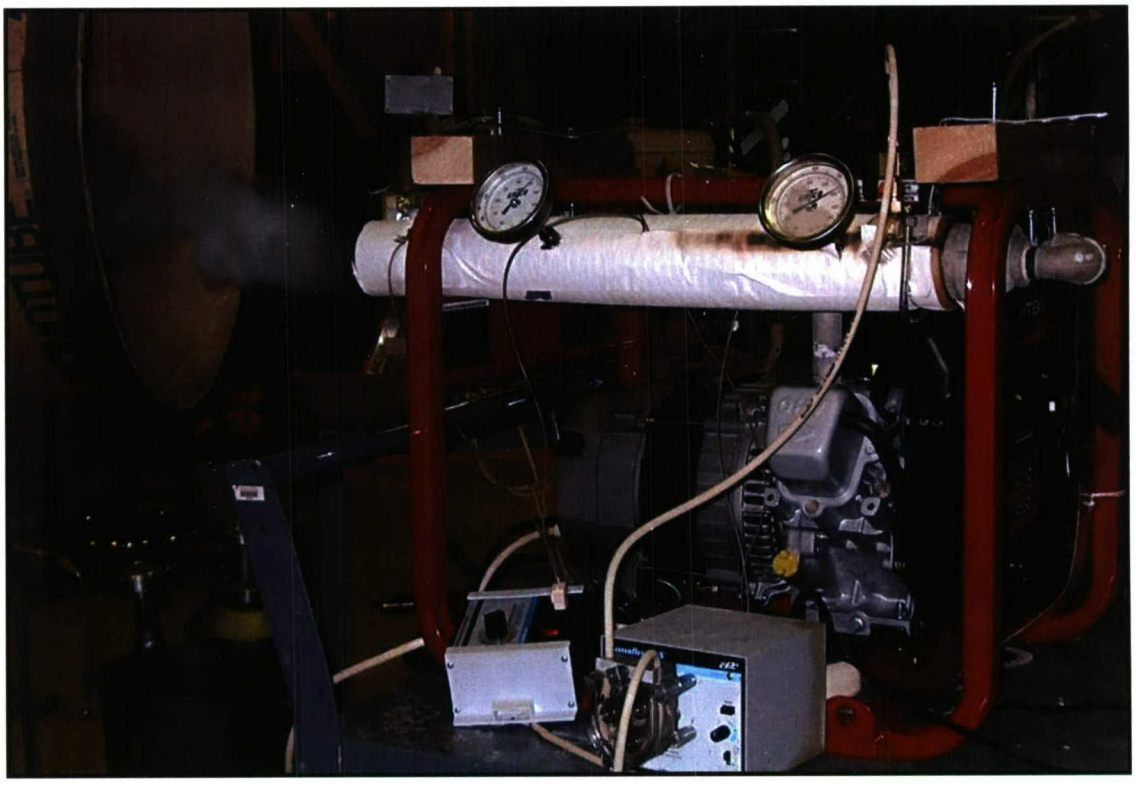

Figure 5. Small Scale Smoke Generator (S3-G) Constructed from a Portable Gas Powered Electric Generator.

2.4 Aerosol Wind Tunnel.

The Open-Jet Aerosol wind tunnel used for testing was operated by the Aerosol Sciences Team, ECBC, R&T Directorate. The Open-Jet Aerosol Wind Tunnel test facility (the "OJ") is an open circuit, continuous flow, subsonic wind tunnel, which was particularly designed to conduct evaluations of aerosol collector inlets, but was easily adapted to other aerodynamic test needs. The OJ features a 1-m diameter open-jet test section, which eliminates wall effects and allows testing of large inlets or objects. The usable jet stream of moving air is then 1.0 m in diameter and 1.2 m long. This allows testing of most sizes of inlets in a velocity range of 4 to 25 mph. The test section area was enclosed by a large plenum (8 ft. x 8 ft. x 8 ft.) at negative atmospheric pressure. Thus aerosol leakage into the lab was prevented and a large area for viewing windows and lighting effects was provided. This tunnel also was unique in its implementation of a "generic mixing system" upstream of the test section to assure good aerosol and flow profiles in the test section.[6]

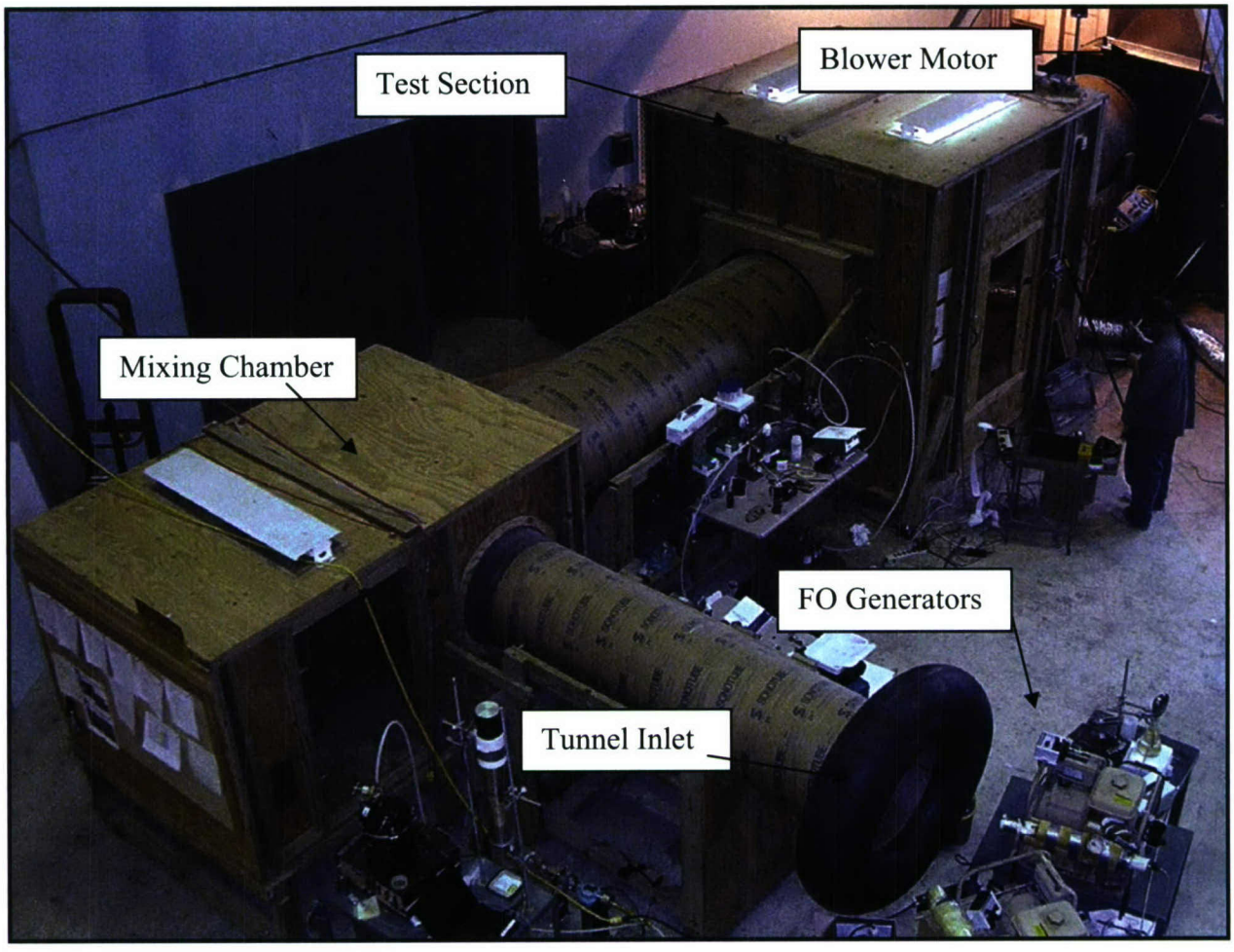

Figure 6. Open Jet Wind Tunnel View from Above.

2.5 Fog Oil Smoke Concentration Measurement.

Fog Oil challenge and penetration concentrations were measured using Real-time Aerosol Sensors, model RAS-2, manufactured by Monitoring Instruments for the Environment (MIE) Inc., Billerica, MA (Figure 7). The RAS-2 sensors were calibrated prior to burrow testing using FO generated by the S3-G and the concentrations were measured using gravimetric analysis of open-faced filter samples.

The RAS-2 is a compact airborne particulate concentration transducer whose operation principle is based on the detection of scattered electromagnetic radiation in the near infrared. The RAS-2 uses a pulsed GaALAs light source, which generates a narrow-band emission centered at 880 nm. This source is operated at an average output power of about 5 mW. The radiation scattered by the airborne particles is sensed over an angular range of approximately 45° to 95° from the forward direction by means of a silicon-photovoltaic hybrid detector with internal low-noise pre-amplification. An optical interference type filter is incorporated to screen out any light whose wavelength differs from that of the source.

Air surrounding the RAS-2 passed freely through an open ended sensing chamber. The RAS-2 required no pump for operation. The scattering sensing parameters were designed for preferential response to particles in the 0.1 to 10 μm size range. The RAS-2 provided an analog output directly proportional to the concentration of airborne particles. The RAS-2 was manufactured for two concentration ranges. The sensors used for this study have a dynamic range of 0.1 to 1000 mg/m^3. Output gain for each of the 4 RAS-2s used was set to 50 mV using a standard scattering window prior to calibration. The RASes used during this study were calibrated simultaneously using fiber filters sampled at iso-kenetic flow rates. Calibration equations were calculated for each RAS and used to quantify FO concentrations measured throughout the study.

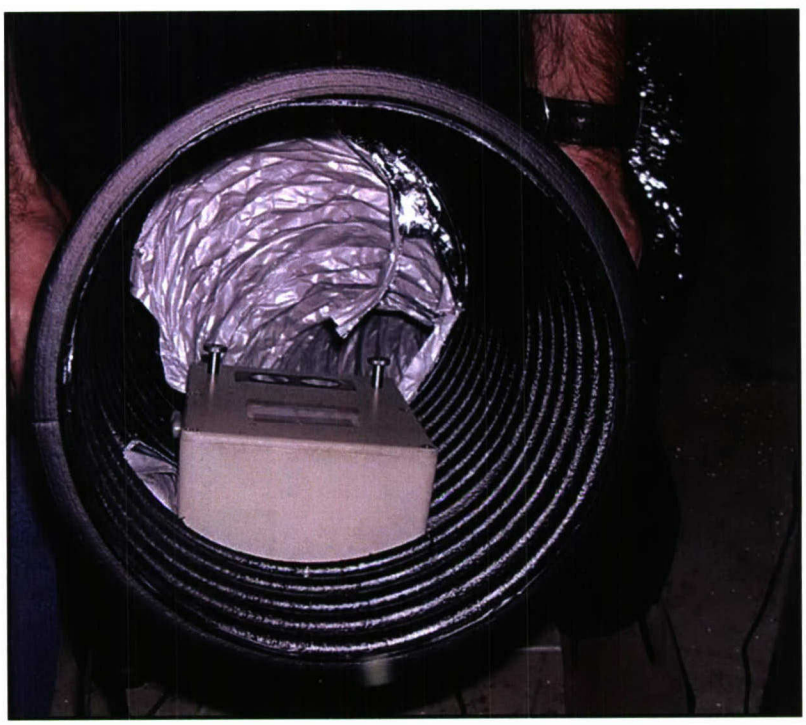

Figure 7. RAS Mounted in Plastic Drainpipe and Installed at End of Model Gopher Tortoise Burrow.

The access holes cut into the corrugated drainpipe were just large enough to allow the mounting of the aerosol sensors. The sensors were positioned so that the sensing volume was as close to the center of the model burrow as possible. The access hole was then sealed to prevent airflow. The end of the model burrow farthest from the inlet was closed with an end-cap and sealed with expanding foam.

Particle size analysis was performed using an 8-stage non-viable Anderson Cascade impactor, Model Mark II. Smoke was sampled with the impactor during the calibration of the RASes. At the time of generation, the FO generator exhaust temperature was 400 °C.

2.6 Data Collection.

Concentration data from the RAS-2 was collected and saved using Omega OM-500 multi-channel data logger. The OM-500 logs analog out data as mV on up to 5 channels. The OM-500 is a portable unit with battery pack for field operation. Data recorded by the OM-500 was downloaded to its accompanying software after each test run. The software allows for simultaneous display of up to 5-data sets. Data for all the test results were entered on an Excel spreadsheet for manipulation and statistical analysis (Figure 8).

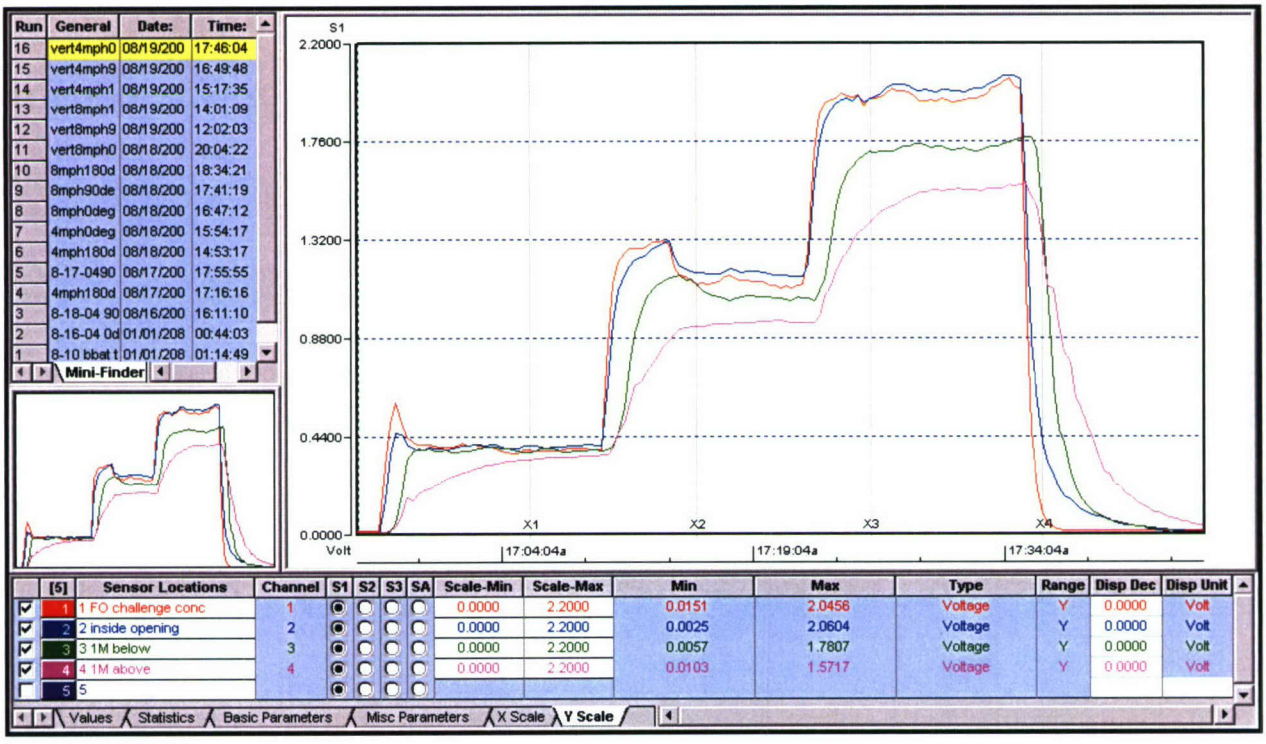

Figure 8. Screenshot from Omega 5 Data Logging Software Displaying Output from 4 RASes from 4 mph, 0°, Vertical, and Model Tree Trunk Test Showing 3 Successive Concentrations.

2.7 Fog Oil.

The FO used for this study was taken from a 55-gallon drum already in stock and was labeled in the following manner:

9150-00-261-7895	National Stock Number
CAGE/Prime 0A9L8	"Commercial and Government Entity"/Contractor ID Number
FO 1DR Net Wt. 413 lbs.	
M 10 08/03 MFD 08/03	Manufactured Date August 2003
Test and Re-inspect 08/06	Shelf Life 3yrs, Re-test in August 06
MIL-PRF-12070F	Military Performance Specification Number
Flash Pt. 333 °F, 167 °C	
Boiling Pt. 621 °F, 327 °C	
Lot. D2163	
SP0450-98-D-4153-0340	Contract Number from FY98
HOC Industries Inc.	
3511 N. Ohio, Wichita, KS 67219-3721	

2.8 Test Matrix.

The test design for this study was to expose each model to 3 concentrations of FO, using 3 different wind speeds at 3 orientations to wind direction, thereby subjecting each model to 27-test series. After testing the model Gopher Tortoise Burrow and prior to testing the model tree trunk, concern was raised over potential settling effects from a horizontally positioned trunk model. The test matrix was changed to include the vertical and horizontal positioning of the model tree cavity. The test matrices are represented in Tables 1 and 2 below.

Table 1. Fog Oil Challenge Testing Matrix for Model Gopher Tortoise Burrow.

Wind speed (mph)	**FO Concentrations (mg/m^3)**	**Orientations (Degrees to Direction)**	**Tests* (Count)**
4	50, 150, 300	0, 90, 180	9
8	50, 150, 300	0, 90, 180	9
12	50, 150, 300	0, 90, 180	9

*Total No. of Tests: 27

Table 2. Fog Oil Challenge Testing Matrix for Model Tree Trunk Cavity.

Wind Speed (mph)	Concentrations Vertical Position (mg/m^3)	Concentrations Horizontal Position (mg/m^3)	Orientations (Degrees to Direction)	Tests* (Count)
4	50, 150, 300	50, 150, 300	0, 90, 180	27
8	50, 150	50, 150	0, 90, 180	12

*Total No. of Tests: 39

3. DATA AND RESULTS

3.1 Real-Time Aerosol Sensor Calibration.

Aerosol sensors were calibrated simultaneously by recording RAS output in millivolts versus weight of FO collected on glass fiber filters. Calibration equations were determined by linear regression of recorded data. Calibration data are displayed in Figures 9 to 12. RAS-1 was used throughout the study to record challenge FO concentration.

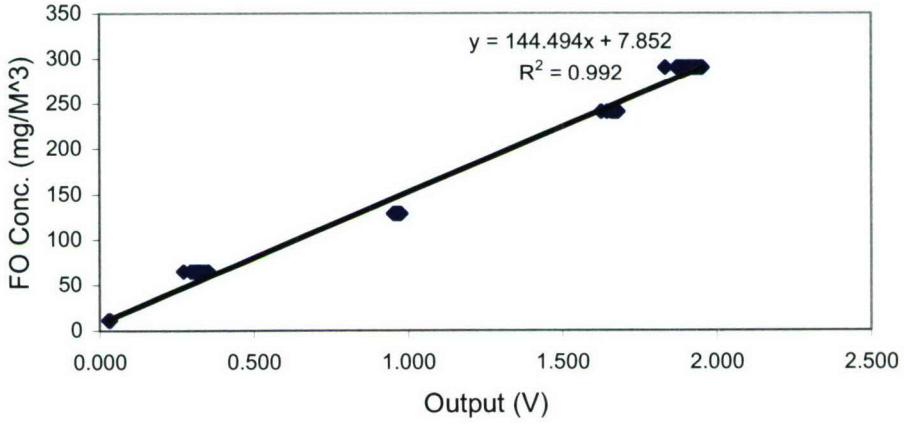

Figure 9. Linear Regression Calibration of RAS-1

The RAS-2 was used throughout the study to measure FO concentration 1 m inside the Model Gopher Tortoise Burrow and just inside the Model Tree Trunk Nest Cavity.

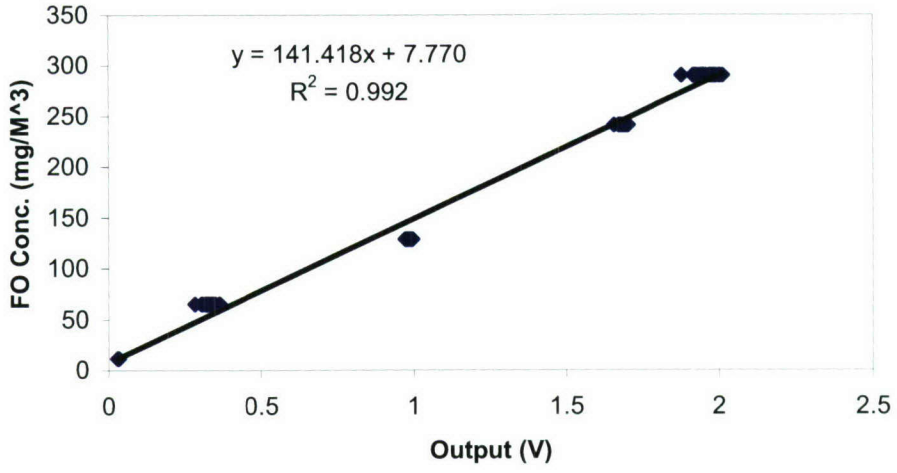

Figure 10. Linear Regression Calibration of RAS-2.

A RAS-3 was used to measure FO penetration concentrations in the Model Gopher Tortoise Burrow at the 3-m point into the Model Burrow and in the Model Tree Cavity 1 m left of or 1 m below the entrance.

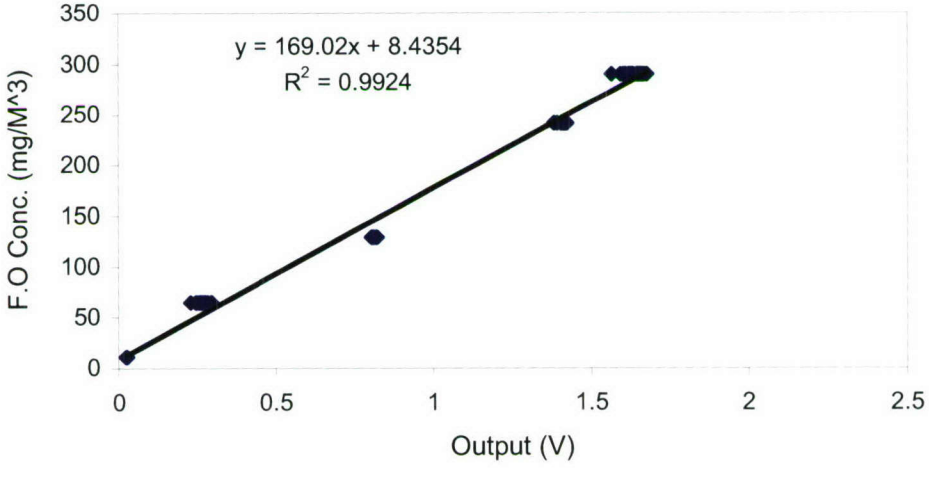

Figure 11. Linear Regression Calibration of RAS-3.

RAS-4 was used to measure FO penetration concentrations in the model gopher tortoise burrow at the 5-m point into the model burrow and in the model tree trunk cavity 1 m left of or 1 m above the entrance.

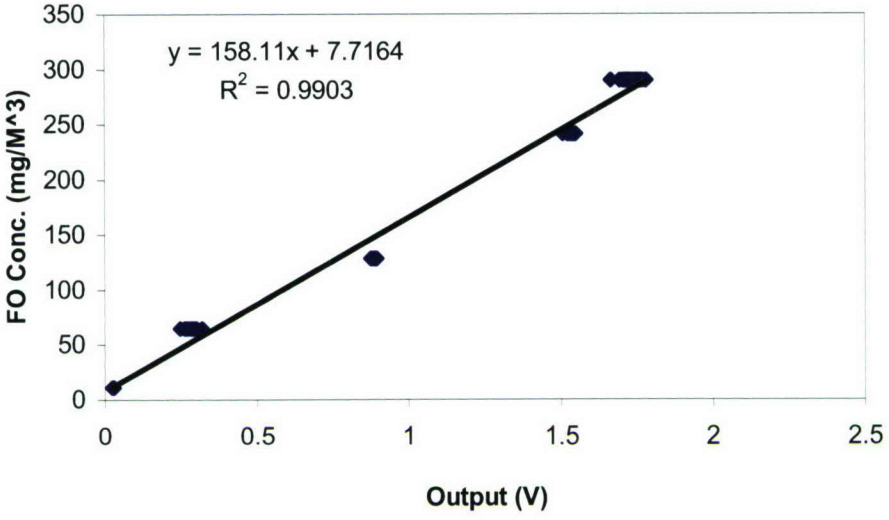

Figure 12. Linear Regression Calibration of RAS-4.

Challenge FO particle Aerodynamic Mass Mean Diameter was measured at 0.58 microns. This FO particle size falls in the lower range,[7] but is realistic for a freshly generated smoke that was produced at lower initial plume concentrations. Data was entered into an Excel spreadsheet; the program added a best-fit trend line. Figure 13 is a cumulative plot of weight distribution within the Andersen Sampler.

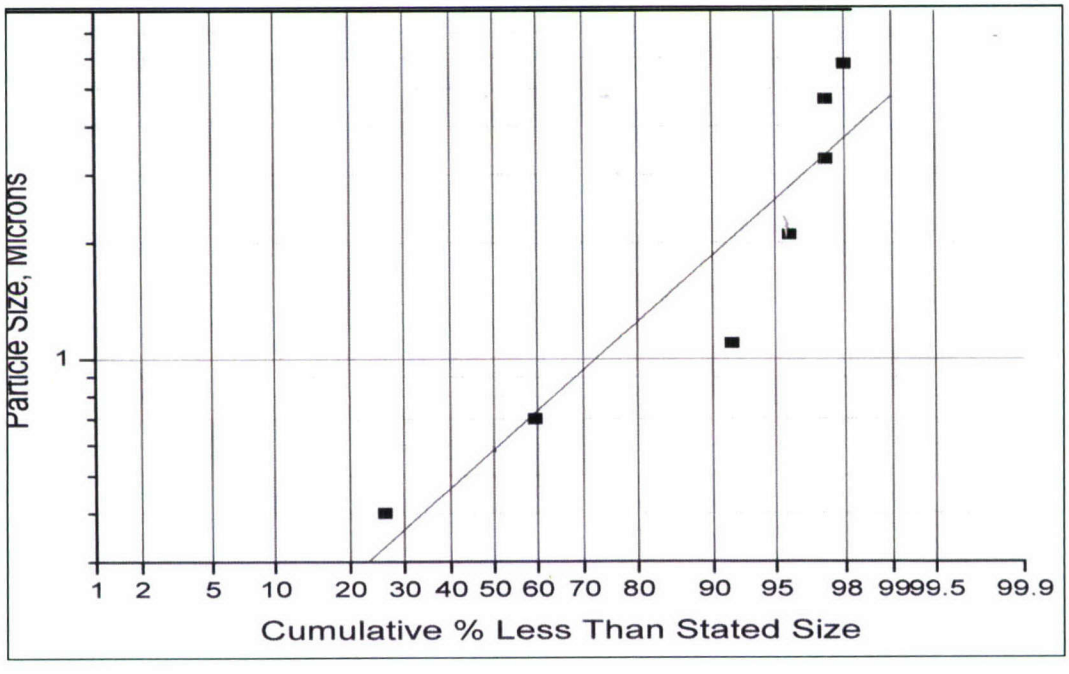

Figure 13. Anderson Sampler Plot of Fog Oil Particle Size Distribution.

3.2 Model Gopher Tortoise Data.

Fog Oil penetration into the Model Gopher Tortoise Burrow was minimal for all the tests conducted. Table 3 presents a summary of the average FO challenge and the penetration concentrations measured. Data for model burrow concentrations are only displayed for 1 m into the burrow. At the 3 m and 5 m points into the burrow, RAS measurements were below detectable levels for the entire study and are not presented here.

Table 3. Summaries of Mean Fog Oil Challenge and Penetration Concentrations Measured during Testing of the Model Gopher Tortoise Burrow.

	Orientation 0°		**Orientation 90°**		**Orientation 180°**	
Wind Speed (mph)	**Challenge Conc. (mg/m^3)**	**FO Penetration 1 m Inside (mg/m^3)**	**Challenge Conc. (mg/m^3)**	**FO Penetration 1 m Inside (mg/m^3)**	**Challenge Conc. (mg/m^3)**	**FO Penetration 1 m Inside (mg/m^3)**
4	50.3	0.0	52.4	0.0	51.1	0.0
4	152.4	0.0	152.4	0.1	153.6	0.0
4	305.0	0.0	301.6	0.3	296.2	0.3
8	51.1	0.0	51.4	0.0	51.3	0.0
8	153.4	0.0	152.5	0.1	161.2	0.1
8	304.0	0.0	299.0	0.4	304.7	0.1
12	51.1	0.0	50.8	0.0	51.7	0.0
12	153.2	0.0	152.4	0.2	164.3	0.0
12	265.6	0.1	281.9	0.3	240.8	0.0

Tables 4-6 present a summary of statistical analysis of Gopher Tortoise FO penetration data.

Table 4. Measured Fog Oil Concentrations and Calculated Descriptive Statistics during Fog Oil Challenge of Model Gopher Tortoise Burrow at 4 mph for 3 Orientations and 3 Concentrations.

	0°		90°		180°	
Calculated Parameter	**Challenge (mg/m^3)**	**1 m (mg/m^3)**	**Challenge (mg/m^3)**	**1 m (mg/m^3)**	**Challenge (mg/m^3)**	**1 m (mg/m^3)**
Mean	50.25	0.01	52.45	0.02	51.05	0.00
Min	48.79	0.00	48.45	0.00	47.50	0.00
Max	53.12	0.03	57.08	0.06	55.17	0.00
Median	50.17	0.01	52.58	0.01	51.29	0.00
Std-D	0.85	0.01	1.65	0.01	1.79	0.00
Count	82.00	82.00	78.00	78.00	80.00	80.00
Mean	152.40	0.02	152.42	0.14	153.55	0.00
Min	138.40	0.01	147.90	0.10	125.92	0.00
Max	159.46	0.03	159.40	0.19	164.04	0.00
Median	152.30	0.03	152.33	0.15	154.46	0.00
Std-D	3.30	0.01	2.29	0.02	6.51	0.00
Count	84.00	84.00	80.00	80.00	123.00	123.00
Mean	305.04	0.03	301.60	0.35	296.20	0.28
Min	300.12	0.01	287.26	0.25	275.61	-0.04
Max	314.89	0.04	325.46	0.45	320.74	0.60
Median	305.05	0.03	300.63	0.35	298.69	0.25
Std-D	2.58	0.01	7.15	0.05	10.83	0.13
Count	81.00	81.00	100.00	100.00	91.00	91.00

Table 5. Measured Fog Oil Concentrations and Calculated Descriptive Statistics during Fog Oil Challenge of Model Gopher Tortoise Burrow at 8 mph for 3 Orientations and 3 Concentrations.

	0°		90°		180°	
Calculated Parameter	**Challenge (mg/m^3)**	**1 m (mg/m^3)**	**Challenge (mg/m^3)**	**1 m (mg/m^3)**	**Challenge (mg/m^3)**	**1 m (mg/m^3)**
Mean	51.09	0.02	51.41	0.02	51.26	0.02
Min	43.12	0.01	48.02	0.00	45.96	0.01
Max	60.81	0.04	53.48	0.04	54.94	0.04
Median	51.65	0.01	51.45	0.01	51.22	0.03
Std-D	4.58	0.01	0.99	0.01	1.65	0.01
Count	37.00	37.00	76.00	76.00	78.00	78.00
Mean	153.37	0.05	152.47	0.15	161.15	0.05
Min	148.17	0.01	147.94	0.13	139.51	0.01
Max	159.18	0.10	161.46	0.19	170.39	0.09
Median	153.11	0.04	151.81	0.15	162.20	0.06
Std-D	2.37	0.02	2.79	0.01	5.26	0.02
Count	73.00	73.00	88.00	88.00	89.00	89.00
Mean	304.00	0.03	298.96	0.43	304.70	0.07
Min	284.88	-0.01	263.12	0.31	289.64	0.03
Max	325.07	0.77	323.79	0.58	311.82	0.10
Median	303.69	0.01	309.51	0.41	305.95	0.09
Std-D	4.39	0.03	19.74	0.08	4.90	0.02
Count	85.00	85.00	88.00	88.00	68.00	60.00

Table 6. Measured Fog Oil Concentrations and Calculated Descriptive Statistics during Fog Oil Challenge of Model Gopher Tortoise Burrow at 12 mph for 3 Orientations and 3 Concentrations.

	0°		90°		180°	
Calculated Parameter	**Challenge (mg/m^3)**	**1 m (mg/m^3)**	**Challenge (mg/m^3)**	**1 m (mg/m^3)**	**Challenge (mg/m^3)**	**1 m (mg/m^3)**
Mean	51.07	-0.01	50.85	0.03	51.72	0.01
Min	48.38	-0.03	48.05	0.00	49.77	0.00
Max	54.10	0.01	55.64	0.06	54.26	0.03
Median	51.06	-0.01	50.61	0.03	51.63	0.01
Std-D	1.24	0.01	1.38	0.01	0.85	0.01
Count	76.00	76.00	78.00	78.00	64.00	64.00
Mean	153.21	0.02	152.39	0.18	164.26	0.03
Min	148.82	0.01	148.05	0.10	161.81	0.01
Max	160.47	0.03	156.80	3.07	166.93	0.04
Median	152.85	0.01	152.14	0.15	164.26	0.03
Std-D	2.50	0.01	1.68	0.35	1.04	0.01
Count	93.00	93.00	72.00	72.00	70.00	70.00
Mean	265.57	0.08	281.90	0.32	240.85	0.04
Min	233.42	0.04	260.33	0.25	26.18	0.01
Max	303.66	0.12	304.56	0.39	261.11	0.07
Median	261.74	0.09	279.93	0.32	37.18	0.03
Std-D	14.98	0.02	8.73	0.03	11.11	0.02
Count	78.00	78.00	71.00	71.00	64.00	64.00

3.3 Model Tree Trunk Data, Horizontal Position.

The model tree trunk cavity was first exposed to the FO challenge in the horizontal position. The length of the model was perpendicular to the direction of the challenge air stream. Testing included challenging the model to 3 concentrations of FO at the 4 mph wind speed and 2 concentrations of FO at the 8 mph wind speed as described in Table 2 of section 2.8. Fog Oil Penetration results and statistical summaries are presented in Tables 7-16.

Location of the aerosol detectors were described as "challenge", "entrance", for the RAS just behind the model cavity opening, and 1 m right or left for each RAS located at either end of the cavity in the horizontal position. The RAS at the location 1 m location was the right end of the model when facing the cavity opening at 0° orientation to the challenge FO.

Table 7. Summary of Average Fog Oil Penetration into the Model Tree Trunk Cavity for Each Test with Model in the Horizontal Position.

Wind Speed (mph)	Orientation (°)	FO Challenge Concentration (mg/m^3)	(%) Penetration Entrance	(%) Penetration 1 m Left	(%) Penetration 1 m Right
4	0	51	105	111	88
4	0	193	107	113	100
4	0	282	111	115	102
4	90	52	18	21	20
4	90	173	9	12	7
4	90	310	9	9	8
4	180	99	36	14	13
4	180	172	35	11	17
4	180	300	35	10	26
8	0	54	104	106	92
8	0	208	105	107	85
8	90	67	15	17	15
8	90	260	8	9	7
8	180	63	33	19	20
8	180	246	29	10	13

Table 8. Measured Fog Oil Concentrations and Percent Penetration into Model Tree Cavity at 4 mph and 0° with Model in Horizontal Position.

Series (mph)	Parameter	Measured FO Concentration				Percent FO Penetration		
		FO Challenge (mg/m^3)	Inside Entrance (mg/m^3)	1 m Left (mg/m^3)	1 m Right (mg/m^3)	Entrance %	1 m Left %	1 m Right %
4 0°	Avg	51.2	53.5	56.9	44.8	104.6	111.1	87.5
	Min	38.5	27.2	19.2	9.0	70.6	70.5	46.9
	Max	90.2	74.3	82.5	57.9	82.4	110.9	70.2
	Std-D	6.5	6.4	8.1	14.1			
	Count	35.0	35.0	35.0	35.0			
	Sample Time (min)	11.7	11.7	11.7	11.7			
4 0°	Avg	193.3	212.6	218.0	192.6	110	112.8	99.6
	Min	170.8	178.5	170.0	148.6	104.5	99.5	87.0
	Max	206.2	222.4	228.9	203.4	107.8	111.0	98.6
	Std-D	6.1	10.1	14.3	15.6			
	Count	31.0	31.0	31.0	31.0			
	Sample Time (min)	10.3	10.3	10.3	10.3			
4 0°	Avg	282.1	314.2	323.5	288.6	111.4	114.7	102.3
	Min	272.1	298.9	292.8	244.2	109.9	107.6	89.8
	Max	309.8	318.9	344.2	319.2	102.9	111.1	103.0
	Std-D	9.9	3.6	9.6	12.0			
	Count	32.0	32.0	32.0	32.0			
	Sample Time (min)	10.7	10.7	10.7	10.7			

Table 9. Measured Fog Oil Concentrations and Percent Penetration into Model Tree Cavity at 4 mph and 90° with Model in Horizontal Position.

Series (mph)	Parameter	Measured FO Concentration				Percent FO Penetration		
		FO Challenge (mg/m^3)	Inside Entrance (mg/m^3)	1 m Left (mg/m^3)	1 m Right (mg/m^3)	Entrance (%)	1 m Left (%)	1 m Right (%)
4 90°	Avg	52.3	9.6	11.1	10.0	18.4	21.2	20.1
	Min	44.9	8.6	10.4	9.4	19.1	23.2	21.9
	Max	55.2	10.5	11.3	10.5	19.0	20.5	20.1
	Std-D	2.9	0.4	0.2	0.4			
	Count	30.0	30.0	30.0	30.0			
	Sample Time (min)	10.0	10.0	10.0	10.0			
4 90°	Avg	173.2	16.2	20.0	12.9	9.4	11.5	7.5
	Min	161.0	13.0	19.1	11.7	8.1	11.9	7.3
	Max	181.7	17.6	20.8	14.2	9.7	11.5	7.8
	Std-D	4.7	1.0	0.5	0.7			
	Count	29.0	29.0	29.0	29.0			
	Sample Time (min)	9.7	9.7	9.7	9.7			
4 90°	Avg	310.4	27.5	28.2	23.8	8.8	9.1	7.7
	Min	295.8	18.0	22.8	13.3	6.1	7.7	4.5
	Max	315.5	32.0	29.6	31.2	10.1	9.4	9.9
	Std-D	3.8	3.5	1.5	6.0			
	Count	39.0	39.0	39.0	39.0			
	Sample Time (min)	13.0	13.0	13.0	13.0			

Table 10. Measured Fog Oil Concentrations and Percent Penetration into Model Tree Cavity at 4 mph and 180° with Model in Horizontal Position.

Series (mph)	Parameter	Measured FO Concentration				Percent FO Penetration		
		FO Challenge (mg/m^3)	Inside Entrance (mg/m^3)	1 m Left (mg/m^3)	1 m Right (mg/m^3)	Entrance (%)	1 m Left (%)	1 m Right (%)
4 180°	Avg	99.5	35.5	13.9	12.5	35.7	13.9	12.6
	Min	94.9	29.6	10.9	9.1	31.1	11.5	9.6
	Max	104.2	38.0	14.6	16.4	36.5	14.0	15.7
	Std-D	3.0	1.7	0.8	2.6			
	Count	33.0	33.0	33.0	33.0			
	Sample Time (min)	11.0	11.0	11.0	11.0			
4 180°	Avg	172.3	59.8	19.1	29.2	34.7	11.1	16.9
	Min	146.3	51.9	15.3	16.7	35.5	10.5	11.4
	Max	193.3	69.9	21.6	42.6	36.2	11.2	22.0
	Std-D	13.0	4.7	1.3	7.3			
	Count	43.0	43.0	43.0	43.0			
	Sample Time (min)	14.3	14.3	14.3	14.3			
4 180°	Avg	299.6	104.6	30.0	76.8	34.9	10.0	25.6
	Min	275.7	97.9	25.2	49.0	35.5	9.2	17.8
	Max	325.7	114.8	32.3	88.6	35.3	9.9	27.2
	Std-D	11.4	3.5	1.4	9.2			
	Count	41.0	41.0	41.0	41.0			
	Sample Time (min)	13.7	13.7	13.7	13.7			

Table 11. Measured Fog Oil Concentrations and Percent Penetration into Model Tree Cavity at 8 mph, 0°, 90°, and 180° with Model in Horizontal Position.

Series (mph)	Parameter	Measured FO Concentration				Percent FO Penetration		
		FO Challenge (mg/m^3)	Inside Entrance (mg/m^3)	1 m Left (mg/m^3)	1 m Right (mg/m^3)	Entrance (%)	1 m Left (%)	1 m Right (%)
	Avg	54.3	56.7	57.8	50.0	104.5	106.5	92.1
	Min	41.9	49.9	48.6	34.1	119.0	115.9	81.4
8	Max	57.4	59.2	60.0	54.9	103.1	104.6	95.6
0°	Std-D	2.6	1.8	2.4	6.1			
	Count	30.0	30.0	30.0	30.0			
	Sample Time (min)	10.0	10.0	10.0	10.0			
	Avg	208.4	219.5	223.9	177.3	105.4	107.5	85.1
	Min	194.1	209.2	198.7	66.8	107.8	102.4	34.4
8	Max	225.2	231.9	237.1	196.4	103.0	105.3	87.2
0°	Std-D	9.7	6.1	7.6	33.1			
	Count	37.0	37.0	37.0	37.0			
	Sample Time (min)	12.3	12.3	12.3	12.3			
	Avg	67.4	10.1	11.8	10.1	15.0	17.5	15.0
	Min	64.9	9.9	11.6	9.6	15.3	17.9	14.8
8	Max	71.5	10.5	12.0	10.3	14.7	16.7	14.4
90°	Std-D	1.8	0.2	0.1	0.2			
	Count	41.0	41.0	41.0	41.0			
	Sample Time (min)	13.7	13.7	13.7	13.7			
	Avg	260.3	20.9	23.5	17.1	8.0	9.0	6.6
	Min	247.1	18.3	22.5	13.0	7.4	9.1	5.2
8	Max	264.1	22.9	24.0	19.2	8.7	9.1	7.3
90°	Std-D	3.0	0.8	0.3	2.0			
	Count	37.0	37.0	37.0	37.0			
	Sample Time (min)	12.3	12.3	12.3	12.3			
	Avg	63.5	21.2	12.0	12.8	33.4	18.9	20.2
	Min	60.5	20.5	11.8	12.0	33.9	19.5	19.8
8	Max	72.7	24.0	12.9	13.3	33.0	17.7	18.3
180°	Std-D	2.0	0.6	0.2	0.3			
	Count	43.0	43.0	43.0	43.0			
	Sample Time (min)	14.3	14.3	14.3	14.3			
	Avg	245.9	71.8	24.1	32.9	29.2	9.8	13.4
	Min	237.0	68.3	23.6	22.0	28.8	10.0	9.3
8	Max	261.3	75.0	24.9	40.0	28.7	9.5	15.3
180°	Std-D	5.8	1.8	0.3	5.0			
	Count	30.0	30.0	30.0	30.0			
	Sample Time (min)	10.0	10.0	10.0	10.0			

3.4 Model Tree Trunk Data, Vertical Position.

Table 12. Summary of Average Fog Oil Penetration into the Model Tree Trunk Cavity for Each Test with Model in the Vertical Position

Wind Speed (mph)	FO Challenge Orientation (°)	FO Challenge Concentration (mg/m^3)	% Penetration Entrance	Penetration 1 m Below	Penetration 1 m Above
4	0	64	99	114	87
4	0	177	100	107	85
4	0	293	99	102	83
4	90	64	15	18	15
4	90	171	9	10	7
4	90	293	7	8	6
4	180	57	34	21	28
4	180	178	31	11	24
4	180	300	42	10	34
8	0	61	109	109	82
8	0	241	99	101	84
8	90	60	16	18	16
8	90	246	7	8	6
8	180	48	32	22	21
8	180	234	23	10	15

Table 13. Measured Fog Oil Concentrations and Percent Penetration into Model Tree Cavity at 4 mph and 0° with Model in Vertical Position.

Series (mph)	Parameter	Measured FO Concentration				Percent FO Penetration		
		FO Challenge (mg/m^3)	Inside Entrance (mg/m^3)	1 m Below (mg/m^3)	1 m Above (mg/m^3)	Entrance (%)	1 m Below (%)	1 m Above (%)
V 4 0°	Avg	64.2	63.8	73.0	55.9	99.5	113.8	87.1
	Min	60.8	61.8	70.9	32.5	101.5	116.6	53.5
	Max	68.3	65.2	75.1	64.4	95.5	110.0	94.3
	Std-D	1.8	1.0	1.1	9.0			
	Count	35.0	35.0	35.0	35.0			
	Sample Time (min)	11.7	11.7	11.7	11.7			
V 4 0°	Avg	176.9	177.1	190.3	150.5	100.1	107.5	85.0
	Min	167.6	170.9	160.9	113.5	101.9	94.1	67.7
	Max	197.5	193.9	204.6	159.4	98.2	105.5	80.7
	Std-D	10.4	6.7	8.6	13.2			
	Count	31.0	31.0	31.0	31.0			
	Sample Time (min)	10.3	10.3	10.3	10.3			
V 4 0°	Avg	292.5	289.9	297.8	241.6	99.1	101.8	82.6
	Min	285.4	280.7	257.1	194.6	98.4	90.1	68.2
	Max	303.4	299.1	308.1	255.4	98.6	101.5	84.2
	Std-D	4.1	4.8	10.0	16.4			
	Count	34.0	34.0	34.0	34.0			
	Sample Time (min)	11.3	11.3	11.3	11.3			

Table 14. Measured Fog Oil Concentrations and Percent Penetration into Model Tree Cavity at 4 mph and 90° with Model in Vertical Position.

Series (mph)	Parameter	Measured FO Concentration				Percent FO Penetration		
		FO Challenge (mg/m^3)	Inside Entrance (mg/m^3)	1 m Below (mg/m^3)	1 m Above (mg/m^3)	Entrance (%)	1 m Below (%)	1 m Above (%)
V 4 90°	Avg	64.3	9.8	11.3	9.6	15.3	17.5	15.0
	Min	57.3	9.2	11.0	8.9	16.1	19.1	15.6
	Max	68.6	10.1	11.5	10.1	14.7	16.8	14.7
	Std-D	2.6	0.2	0.1	0.3			
	Count	36.0	36.0	36.0	36.0			
	Sample Time (min)	12.0	12.0	12.0	12.0			
V 4 90°	Avg	171.0	14.6	16.4	12.6	8.6	9.6	7.3
	Min	165.7	14.1	15.9	10.3	8.5	9.6	6.2
	Max	199.8	15.4	17.3	13.5	7.7	8.7	6.7
	Std-D	6.4	0.3	0.4	0.9			
	Count	34.0	34.0	34.0	34.0			
	Sample Time (min)	11.3	11.3	11.3	11.3			
V 4 90°	Avg	293.2	20.8	22.9	18.0	7.1	7.8	6.2
	Min	288.4	20.0	22.1	17.7	6.9	7.7	6.1
	Max	297.9	23.2	24.4	18.9	7.8	8.2	6.3
	Std-D	2.7	0.7	0.5	0.2			
	Count	35.0	35.0	35.0	35.0			
	Sample Time (min)	11.7	11.7	11.7	11.7			

Table 15. Measured Fog Oil Concentrations and Percent Penetration into Model Tree Cavity at 4 mph and 180° with Model in Vertical Position.

Series (mph)	Parameter	Measured FO Concentration				Percent FO Penetration		
		FO Challenge (mg/m^3)	Inside Entrance (mg/m^3)	1 m Below (mg/m^3)	1 m Above (mg/m^3)	Entrance (%)	1 m Below (%)	1 m Above (%)
V 4 180°	Avg	56.6	19.5	11.6	15.6	34.4	20.5	27.5
	Min	52.3	17.6	11.4	11.4	33.6	21.9	21.8
	Max	64.1	24.2	12.1	17.4	37.7	18.9	27.1
	Std-D	3.0	1.5	0.2	1.5			
	Count	34.0	34.0	34.0	34.0			
	Sample Time (min)	11.3	11.3	11.3	11.3			
V 4 180°	Avg	178.3	55.5	19.7	42.3	31.2	11.0	23.7
	Min	170.1	39.9	18.0	29.0	23.4	10.6	17.1
	Max	247.0	72.6	21.1	51.9	29.4	8.6	21.0
	Std-D	13.3	7.4	0.8	5.3			
	Count	40.0	40.0	40.0	40.0			
	Sample Time (min)	13.3	13.3	13.3	13.3			
V 4 180°	Avg	300.2	127.1	30.1	101.5	42.3	10.0	33.8
	Min	289.2	112.7	29.1	92.3	39.0	10.0	31.9
	Max	309.8	141.4	31.0	110.3	45.6	10.0	35.6
	Std-D	4.4	7.1	0.5	4.8			
	Count	35.0	35.0	35.0	35.0			
	Sample Time (min)	11.7	11.7	11.7	11.7			

Table 16. Measured Fog Oil Concentrations and Percent Penetration into Model Tree Cavity at 8 mph, 0°, 90°, and 180° with Model in Vertical Position.

Series (mph)	Parameter	Measured FO Concentration				Percent FO Penetration		
		FO Challenge (mg/m^3)	Inside Entrance (mg/m^3)	1 m Below (mg/m^3)	1 m Above (mg/m^3)	Entrance (%)	1 m Below (%)	1 m Above (%)
V 8 0°	Avg	61.0	66.1	66.5	49.8	108.5	109.1	81.7
	Min	53.2	60.3	48.6	22.2	113.4	91.3	41.7
	Max	63.3	68.7	69.5	57.4	108.6	109.8	90.7
	Std-D	1.7	1.6	3.3	10.1			
	Count	37.0	37.0	37.0	37.0			
	Sample Time (min)	12.3	12.3	12.3	12.3			
V 8 0°	Avg	241.1	239.9	244.1	203.1	99.5	101.2	84.2
	Min	233.5	232.0	221.0	121.3	99.4	94.7	51.9
	Max	251.5	249.5	253.7	218.7	99.2	100.9	86.9
	Std-D	5.5	4.9	6.1	25.1			
	Count	42.0	42.0	42.0	42.0			
	Sample Time (min)	14.0	14.0	14.0	14.0			
V 8 90°	Avg	60.1	9.4	10.8	9.7	15.7	17.9	16.1
	Min	52.7	9.1	10.5	9.0	17.4	19.9	17.0
	Max	68.1	9.6	11.0	10.0	14.1	16.1	14.6
	Std-D	3.4	0.1	0.1	0.3			
	Count	43.0	43.0	43.0	43.0			
	Sample Time (min)	14.3	14.3	14.3	14.3			
V 8 90°	Avg	246.2	17.5	19.1	15.2	7.1	7.8	6.2
	Min	237.7	17.0	18.5	11.7	7.1	7.8	4.9
	Max	261.4	18.0	19.6	16.2	6.9	7.5	6.2
	Std-D	5.9	0.2	0.2	1.3			
	Count	38.0	38.0	38.0	38.0			
	Sample Time (min)	12.7	12.7	12.7	12.7			
V 8 180°	Avg.	48.4	15.4	10.4	10.0	31.8	21.5	20.6
	Min	44.4	13.5	10.2	7.8	30.5	23.1	17.7
	Max	52.0	19.8	10.7	11.7	38.1	20.6	22.6
	Std-D	1.9	1.2	0.1	1.2			
	Count	48.0	48.0	48.0	48.0			
	Sample Time (min)	16.0	16.0	16.0	16.0			
V 8 180°	Avg.	233.7	54.8	23.0	34.7	23.4	9.8	14.8
	Min	220.6	44.0	21.1	18.5	20.0	9.6	8.4
	Max	250.8	68.9	24.2	41.7	27.5	9.7	16.6
	Std-D	8.7	5.8	0.8	6.6			
	Count	35.0	35.0	35.0	35.0			
	Sample Time (min)	11.7	11.7	11.7	11.7			

4. CONCLUSIONS

As designed, this study collected initial Fog Oil (FO) penetration data using a model Gopher Tortoise burrow and Indiana Brown Bat tree nesting cavities. This study was designed to gather initial data under more controlled conditions than possible in the field without the considerable expense of a full-scale field test. As this study attempted to simulate field conditions with limited, but controlled variables, it cannot and should not be considered irrefutable evidence for a potential FO incursion into the respective burrows and nest cavities. This data should be given measured consideration based on the merit of the study as conducted and the additional supportive data.

The data collected from FO smoke challenged to the model Gopher Tortoise burrow indicate a very limited penetration of the FO into the burrow. No FO smoke was detected beyond the sensor positioned 1 m inside the burrow opening. From data presented in Table 4 and in the appendixes the greatest FO penetration occurs with wind direction presented perpendicular to the burrow entrance. At this orientation, the FO penetrating the burrow represents only slightly more than 0.01% of the challenge concentration. Based on this data, it may not be necessary to conduct any further testing on the effects of FO on a tortoise within its burrow. Both the Gopher and Desert tortoises spend considerable time on the surface while feeding and moving about their habitat during social interactions with other tortoises. During these periods, they may be exposed to full FO concentrations subject to terrain, vegetation and atmospheric conditions during smoke dissemination.

Data for the simulated hollow tree cavity suggest a different effect. Examination of the data in Tables 8 and 9, and in the appendixes shows that concentrations within the nest cavity were greatly affected by opening orientation. Concentrations of FO within the cavity closely approximated the challenge concentration when oriented directly into the wind. Concentration of FO within was lowest relative to ambient when the opening was oriented 90° to the wind direction. Internal concentration ranged from 8% relative to ambient to same as ambient. Assuming a random orientation of nest cavity openings within a forested region, a very limited protection would be afforded to cavity occupants. For the most part, concentration was higher in lower portions of the vertical nest cavity from the apparent settling of FO in a less turbulent environment. As noted in the introduction, previous studies relating to the penetration of FO smoke into the nest cavities of the Red-Cockaded Woodpecker (Driver et. al., 2002, Guelta and Checkai 2001), found that penetration ranged from 60% to 80% + of the ambient level. The larger opening of the tree cavity model in this study suggested that penetration was likely to be high, and this was borne out in the results. Thus, if further examination of the potential for FO smoke to affect the health of the Indiana bat, or other bat species, is conducted, no level of protection for the individuals inside the tree cavity should be assumed. This result should be taken into account in the calculations when and if risk assessments are prepared.

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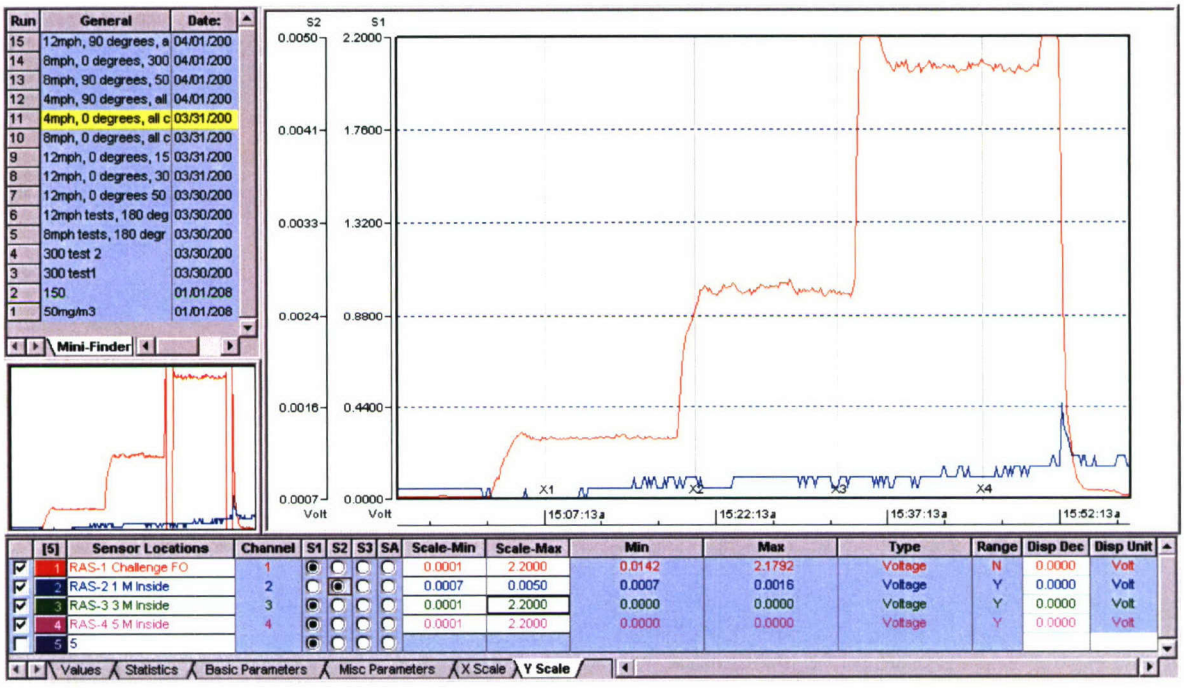
APPENDIX A
FOG OIL CONCENTRATION PROFILE FOR MODEL GOPHER TORTOISE BURROW TESTING, 4 MPH, 0°, 3 CONCENTRATIONS



4 mph 0°	Challenge (mg/m^3)	1 m (mg/m^3)
Mean	50.25	0.01
Min	48.79	0.00
Max	53.12	0.03
Median	50.17	0.01
Std-D	0.85	0.01
Count	82.00	82.00
Mean	152.40	0.02
Min	138.40	0.01
Max	159.46	0.03
Median	152.30	0.03
Std-D	3.30	0.01
Count	84.00	84.00
Mean	305.04	0.03
Min	300.12	0.01
Max	314.89	0.04
Median	305.05	0.03
Std-D	2.58	0.01
Count	81.00	81.00

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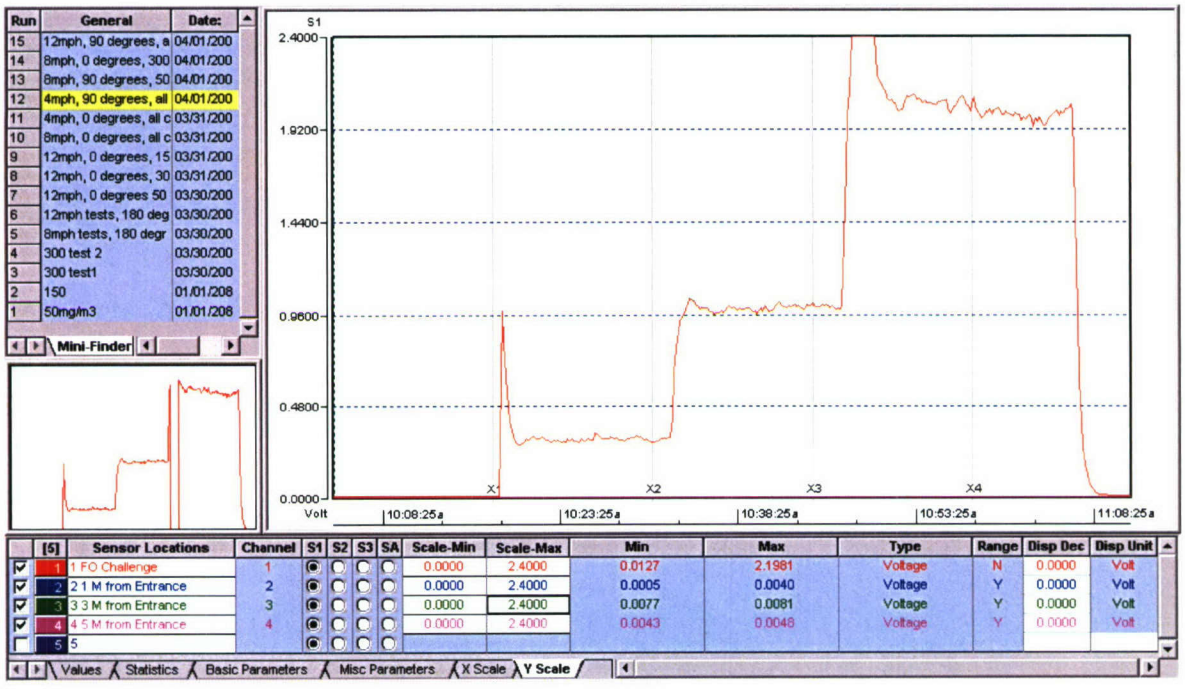
APPENDIX B
FOG OIL CONCENTRATION PROFILE FOR MODEL GOPHER TORTOISE BURROW TESTING, 4 MPH, 90°, 3 CONCENTRATIONS



4 mph 90°	Challenge (mg/m^3)	1 m (mg/m^3)
Mean	52.45	0.02
Min	48.45	0.00
Max	57.08	0.06
Median	52.58	0.01
Std-D	1.65	0.01
Count	78.00	78.00
Mean	152.42	0.14
Min	147.90	0.10
Max	159.40	0.19
Median	152.33	0.15
Std-D	2.29	0.02
Count	80.00	80.00
Mean	301.60	0.35
Min	287.26	0.25
Max	325.46	0.45
Median	300.63	0.35
Std-D	7.15	0.05
Count	100.00	100.00

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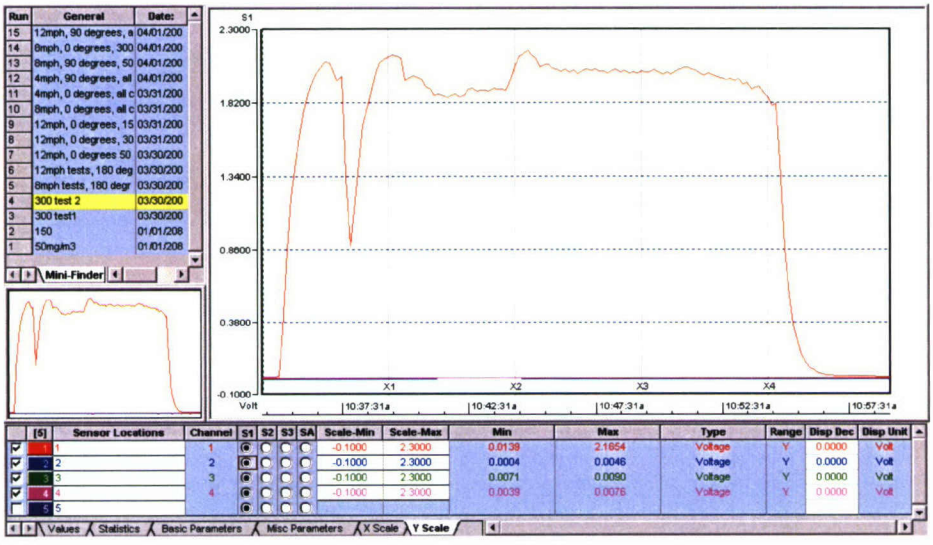
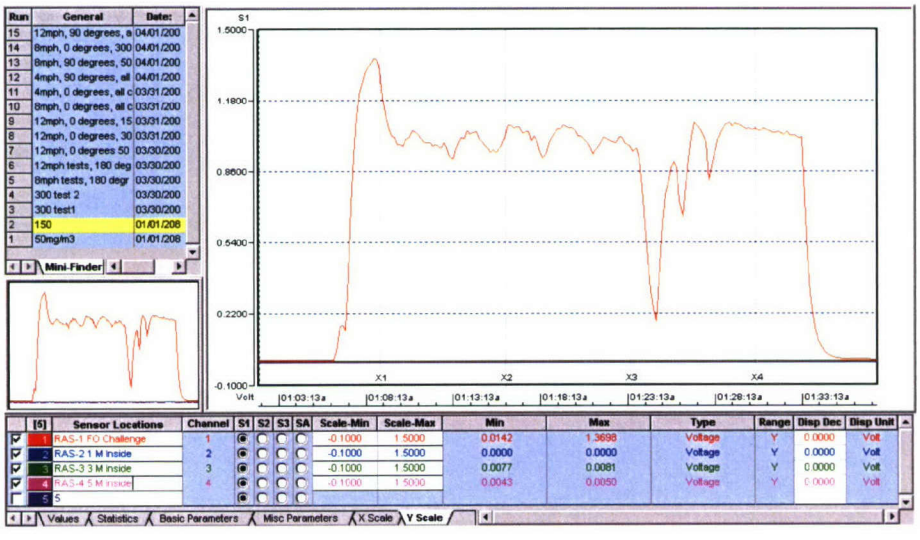
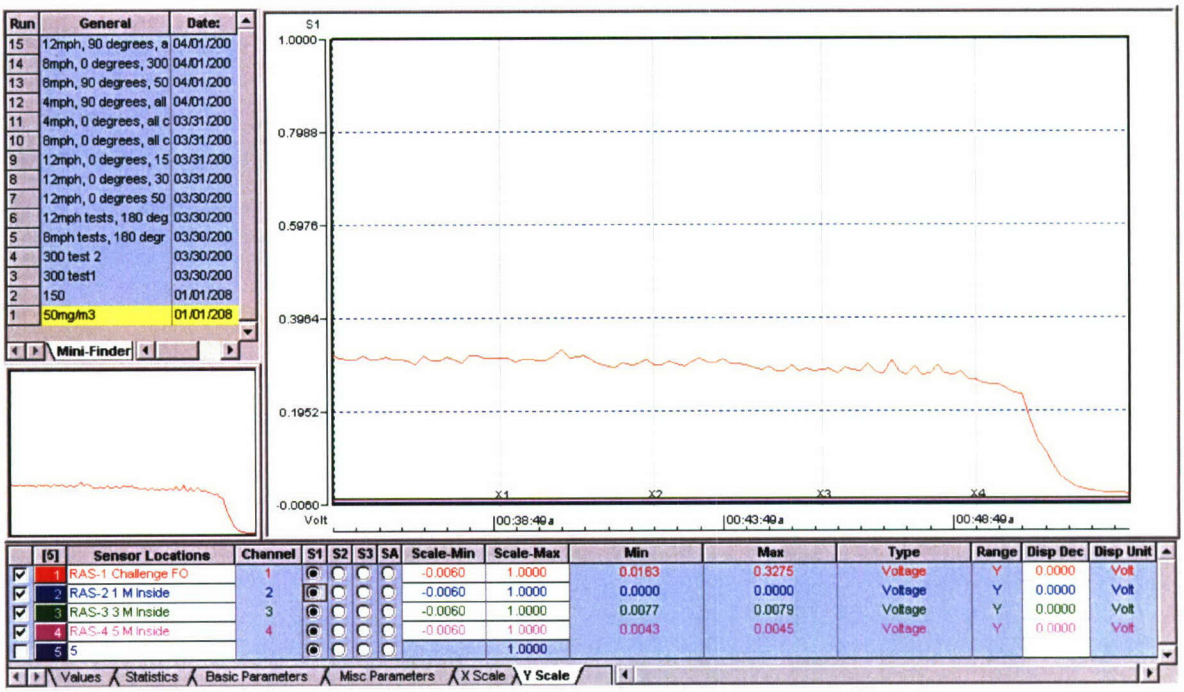
APPENDIX C
FOG OIL CONCENTRATION PROFILE FOR MODEL GOPHER TORTOISE BURROW TESTING, 4 MPH, 180°, 3 CONCENTRATIONS

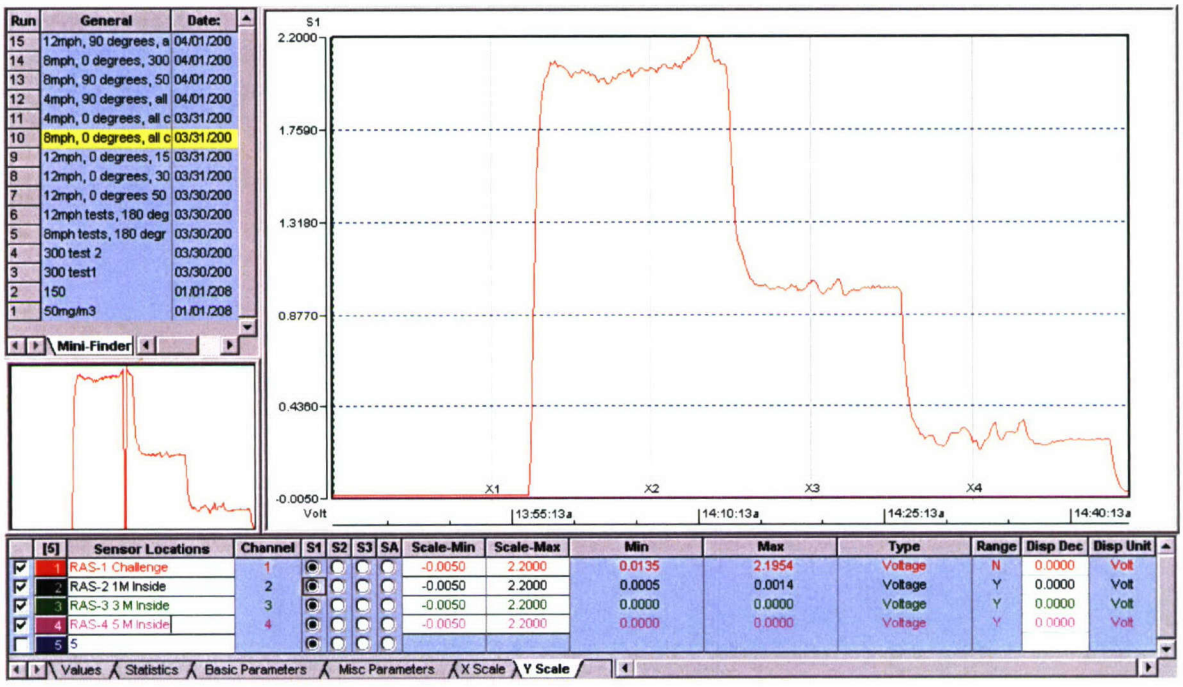






4 mph 180°	Challenge (mg/m^3)	1 m (mg/m^3)
Mean	51.05	0.00
Min	47.50	0.00
Max	55.17	0.00
Median	51.29	0.00
Std-D	1.79	0.00
Count	80.00	80.00
Mean	153.55	0.00
Min	125.92	0.00
Max	164.04	0.00
Median	154.46	0.00
Std-D	6.51	0.00
Count	123.00	123.00
Mean	296.20	0.28
Min	275.61	-0.04
Max	320.74	0.60
Median	298.69	0.25
Std-D	10.83	0.13
Count	91.00	91.00

APPENDIX D
FOG OIL CONCENTRATION PROFILE FOR MODEL GOPHER TORTOISE BURROW TESTING, 8 MPH, 90°, 3 CONCENTRATIONS



8 mph 0°	Challenge (mg/m^3)	1 m (mg/m^3)
Mean	51.09	0.02
Min	43.12	0.01
Max	60.81	0.04
Median	51.65	0.01
Std-D	4.58	0.01
Count	37.00	37.00
Mean	153.37	0.05
Min	148.17	0.01
Max	159.18	0.10
Median	153.11	0.04
Std-D	2.37	0.02
Count	73.00	73.00
Mean	304.00	0.03
Min	284.88	-0.01
Max	325.07	0.77
Median	303.69	0.01
Std-D	4.39	0.03
Count	85.00	85.00

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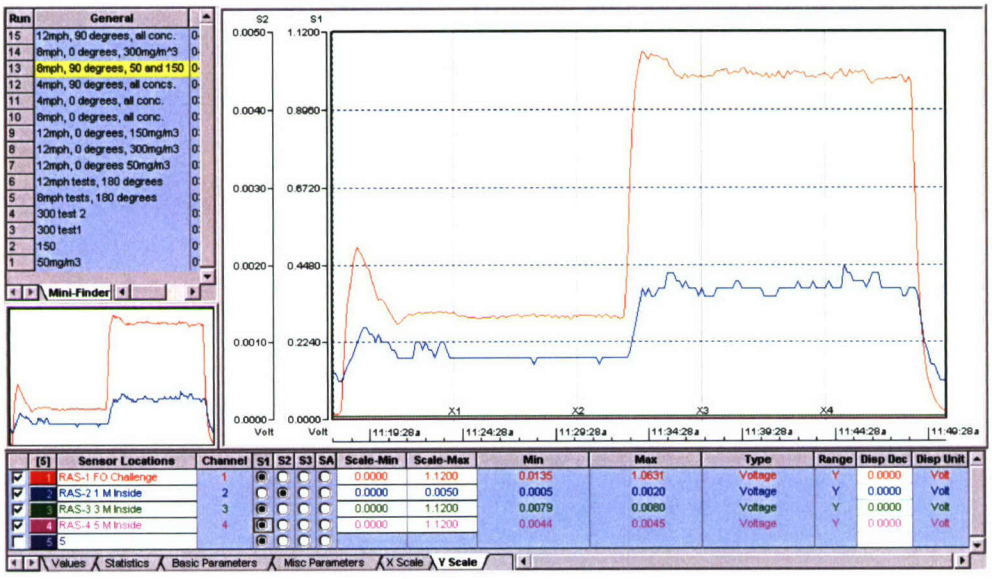
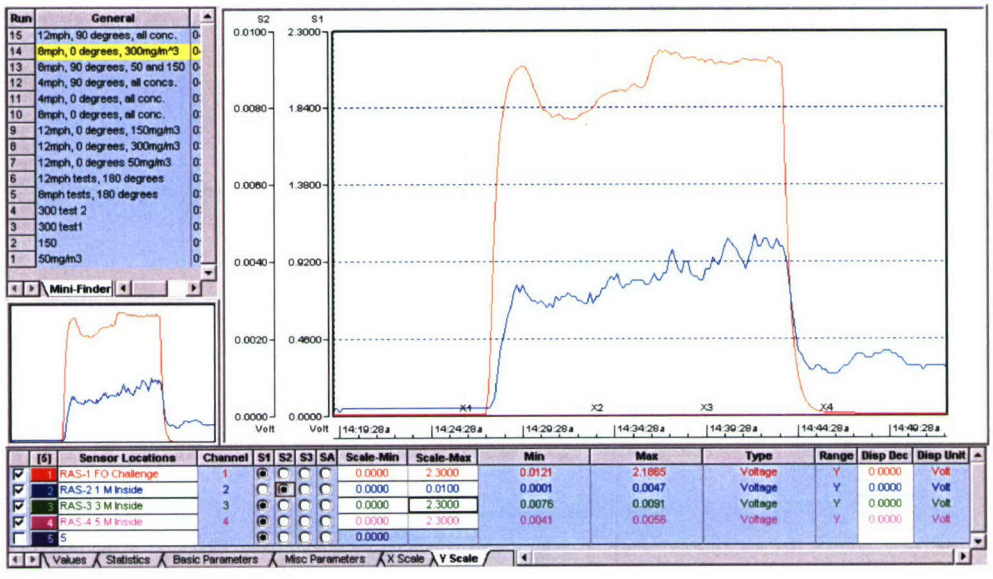
APPENDIX E

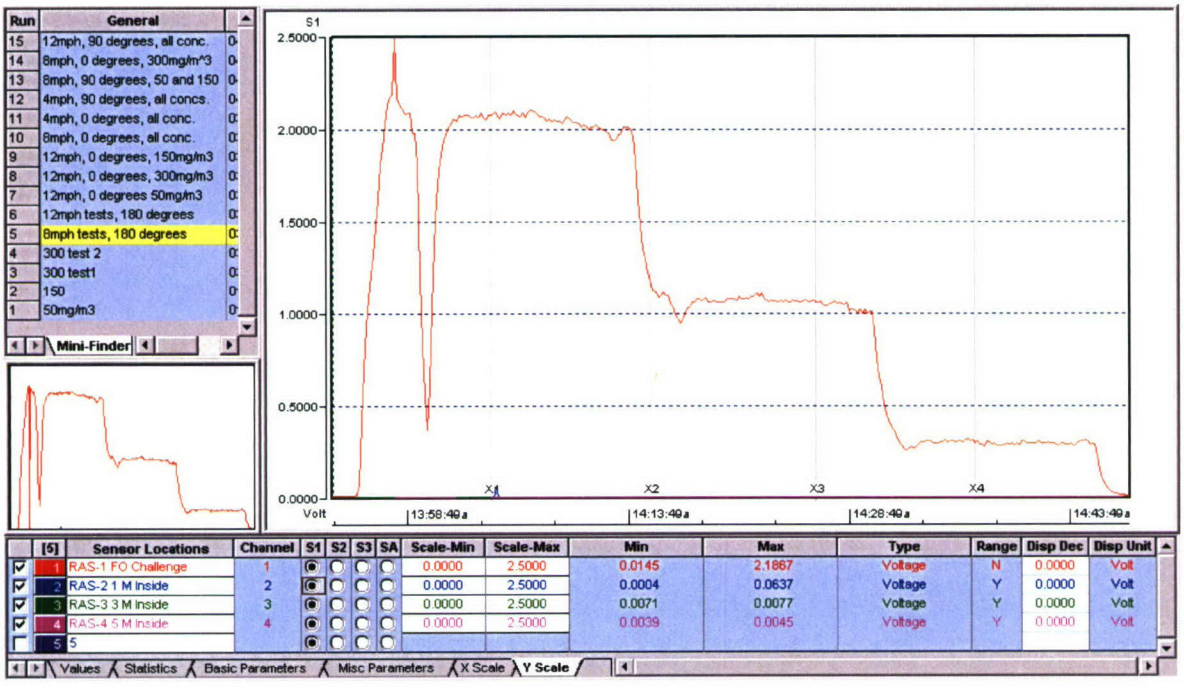
FOG OIL CONCENTRATION PROFILE FOR MODEL GOPHER TORTOISE BURROW TESTING, 8 MPH, 90°, 3 CONCENTRATIONS





8 mph 90°	Challenge (mg/m^3)	1 m (mg/m^3)
Mean	51.41	0.02
Min	48.02	0.00
Max	53.48	0.04
Median	51.45	0.01
Std-D	0.99	0.01
Count	76	76
Mean	152.47	0.15
Min	147.94	0.13
Max	161.46	0.19
Median	151.81	0.15
Std-D	2.79	0.01
Count	88.00	88.00
Mean	298.96	0.43
Min	263.12	0.31
Max	323.79	0.58
Median	309.51	0.41
Std-D	19.74	0.08
Count	88.00	88.00

APPENDIX F
FOG OIL CONCENTRATION PROFILE FOR MODEL GOPHER TORTOISE BURROW TESTING, 8 MPH, 180°, 3 CONCENTRATIONS



8 mph 180°	Challenge (mg/m^3)	1 m (mg/m^3)
Mean	51.26	0.02
Min	45.96	0.01
Max	54.94	0.04
Median	51.22	0.03
Stdev	1.65	0.01
Count	78.00	78.00
Mean	161.15	0.05
Min	139.51	0.01
Max	170.39	0.09
Median	162.20	0.06
Std-D	5.26	0.02
Count	89.00	89.00
Mean	304.70	0.07
Min	289.64	0.03
Max	311.82	0.10
Median	305.95	0.09
Std-D	4.90	0.02
Count	68.00	60.00

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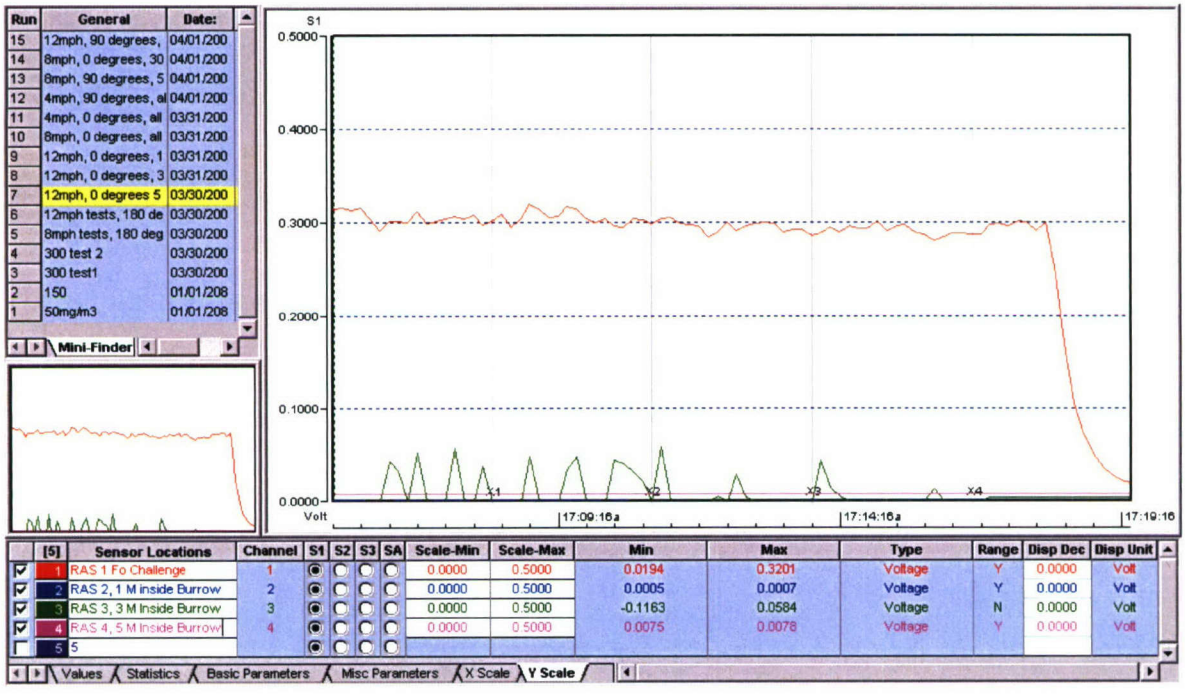
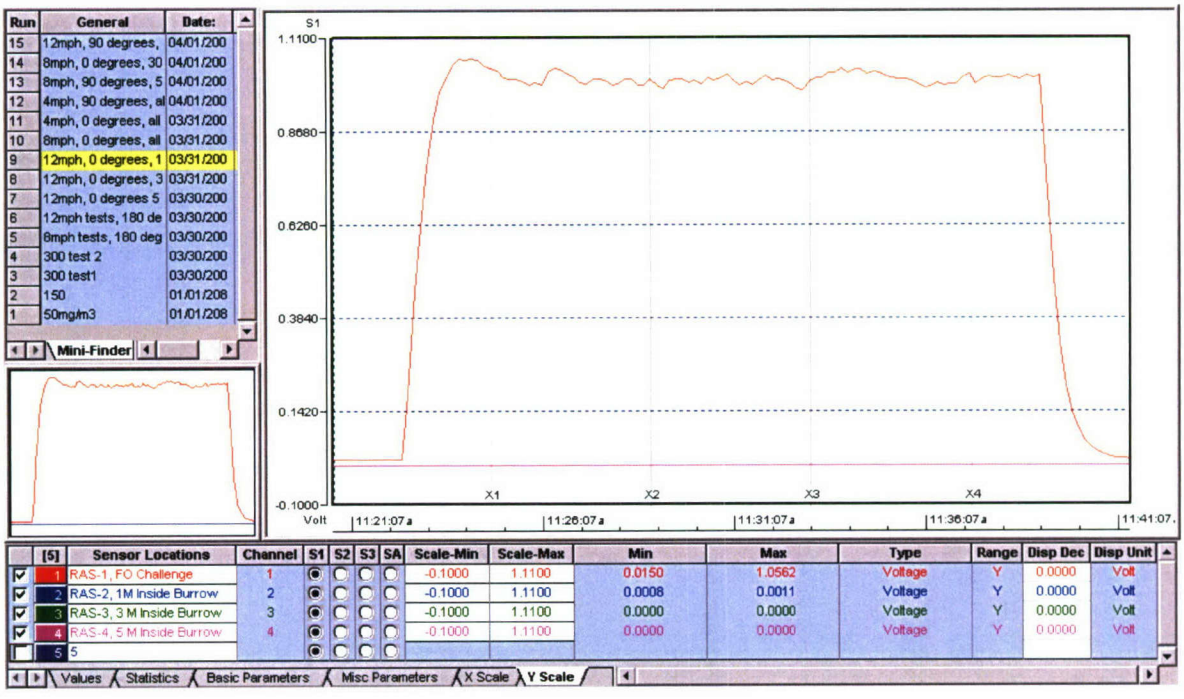
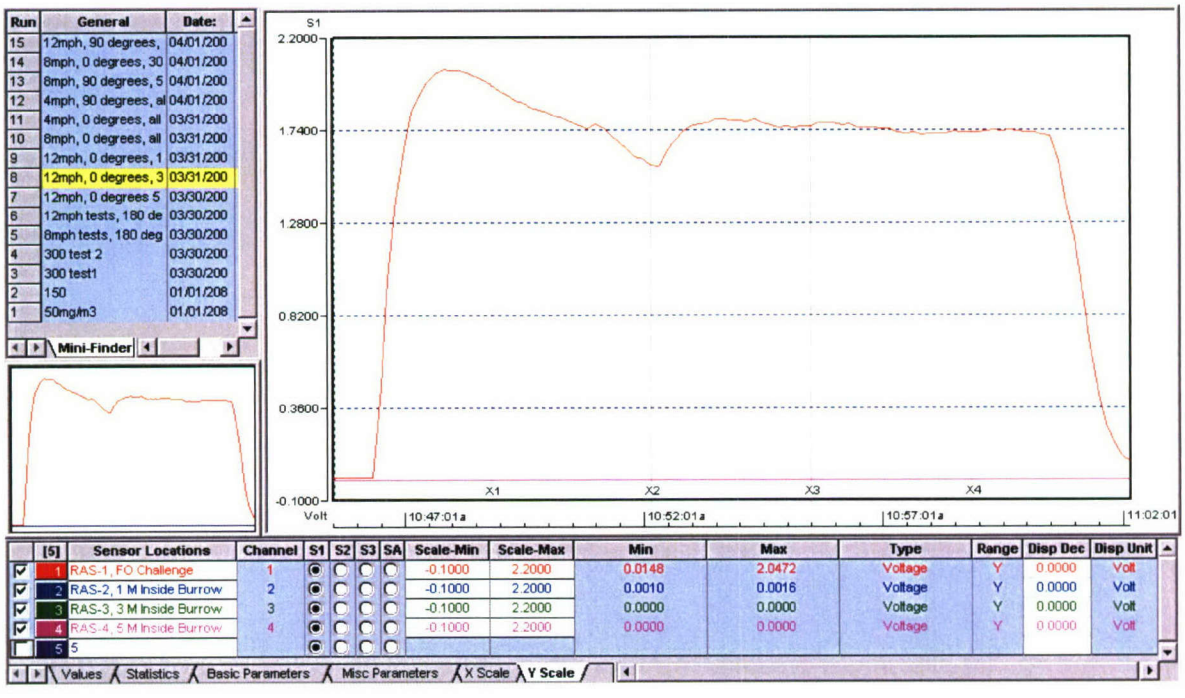
APPENDIX G
FOG OIL CONCENTRATION PROFILE FOR MODEL GOPHER TORTOISE BURROW TESTING,
12 MPH, 0°, 3 CONCENTRATIONS



12 mph 0°	Challenge (mg/m^3)	1 m (mg/m^3)
Mean	51.07	-0.01
Min	48.38	-0.03
Max	54.10	0.01
Median	51.06	-0.01
Std-D	1.24	0.01
Count	76.00	76.00
Mean	153.21	0.02
Min	148.82	0.01
Max	160.47	0.03
Median	152.85	0.01
Std-D	2.50	0.01
Count	93.00	93.00
Mean	265.57	0.08
Min	233.42	0.04
Max	303.66	0.12
Median	261.74	0.09
Std-D	14.98	0.02
Count	78.00	78.00


Run
General
Date:
15 12mph, 90 degrees, 04/01/200
14 8mph, 0 degrees, 30 04/01/200
13 8mph, 90 degrees, 5 04/01/200
12 4mph, 90 degrees, al 04/01/200
11 4mph, 0 degrees, all 03/31/200
10 8mph, 0 degrees, all 03/31/200
9 12mph, 0 degrees, 1 03/31/200
8 12mph, 0 degrees, 3 03/31/200
7 12mph, 0 degrees 5 03/30/200
6 12mph tests, 180 de 03/30/200
5 8mph tests, 180 deg 03/30/200
4 300 test 2 03/30/200
3 300 test1 03/30/200
2 150 01/01/208
1 50mg/m3 01/01/208
Mini-Finder
S1
1.1100
0.8680
0.6260
0.3840
0.1420
-0.1000
Volt
X1
X2
X3
X4
11:21:07a
11:26:07a
11:31:07a
11:36:07a
11:41:07.
[5]
Sensor Locations
Channel
S1
S2
S3
SA
Scale-Min
Scale-Max
Min
Max
Type
Range
Disp Dec
Disp Unit
1 RAS-1, FO Challenge 1 -0.1000 1.1100 0.0150 1.0562 Voltage Y 0.0000 Volt
2 RAS-2, 1M Inside Burrow 2 -0.1000 1.1100 0.0008 0.0011 Voltage Y 0.0000 Volt
3 RAS-3, 3 M Inside Burrow 3 -0.1000 1.1100 0.0000 0.0000 Voltage Y 0.0000 Volt
4 RAS-4, 5 M Inside Burrow 4 -0.1000 1.1100 0.0000 0.0000 Voltage Y 0.0000 Volt
5 5
Values
Statistics
Basic Parameters
Misc Parameters
X Scale
Y Scale


Run
General
Date:
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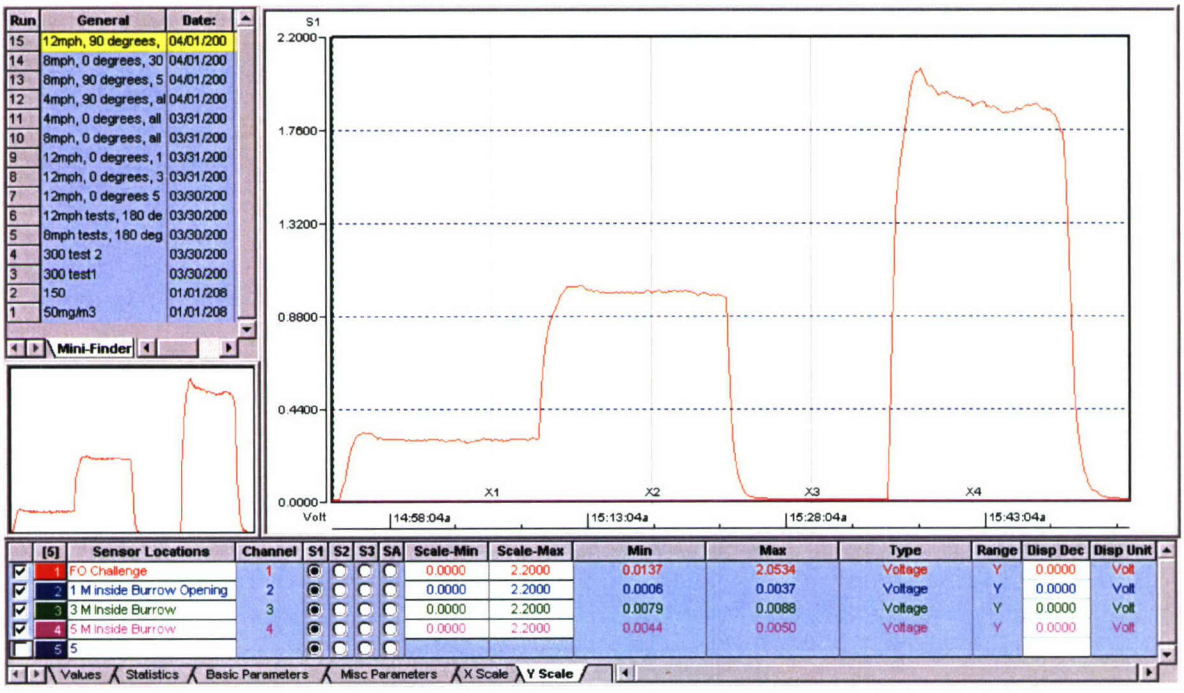
14 8mph, 0 degrees, 30 04/01/200
13 8mph, 90 degrees, 5 04/01/200
12 4mph, 90 degrees, al 04/01/200
11 4mph, 0 degrees, all 03/31/200
10 8mph, 0 degrees, all 03/31/200
9 12mph, 0 degrees, 1 03/31/200
8 12mph, 0 degrees, 3 03/31/200
7 12mph, 0 degrees 5 03/30/200
6 12mph tests, 180 de 03/30/200
5 8mph tests, 180 deg 03/30/200
4 300 test 2 03/30/200
3 300 test1 03/30/200
2 150 01/01/208
1 50mg/m3 01/01/208
Mini-Finder
S1
2.2000
1.7400
1.2800
0.8200
0.3600
-0.1000
Volt
X1
X2
X3
X4
10:47:01a
10:52:01a
10:57:01a
11:02:01
[5]
Sensor Locations
Channel
S1
S2
S3
SA
Scale-Min
Scale-Max
Min
Max
Type
Range
Disp Dec
Disp Unit
1 RAS-1, FO Challenge 1 -0.1000 2.2000 0.0148 2.0472 Voltage Y 0.0000 Volt
2 RAS-2, 1 M Inside Burrow 2 -0.1000 2.2000 0.0010 0.0016 Voltage Y 0.0000 Volt
3 RAS-3, 3 M Inside Burrow 3 -0.1000 2.2000 0.0000 0.0000 Voltage Y 0.0000 Volt
4 RAS-4, 5 M Inside Burrow 4 -0.1000 2.2000 0.0000 0.0000 Voltage Y 0.0000 Volt
5 5
Values
Statistics
Basic Parameters
Misc Parameters
X Scale
Y Scale

APPENDIX H
FOG OIL CONCENTRATION PROFILE FOR MODEL GOPHER TORTOISE BURROW TESTING, 12 MPH, 90°, 3 CONCENTRATIONS



12 mph 90°	Challenge (mg/m^3)	1 m (mg/m^3)
Mean	50.85	0.03
Min	48.05	0.00
Max	55.64	0.06
Median	50.61	0.03
STD-D	1.38	0.01
Count	78.00	78.00
Mean	152.39	0.18
Min	148.05	0.10
Max	156.80	3.07
Median	152.14	0.15
STD-D	1.68	0.35
Count	72.00	72.00
Mean	281.90	0.32
Min	260.33	0.25
Max	304.56	0.39
Median	279.93	0.32
STD-D	8.73	0.03
Count	71.00	71.00

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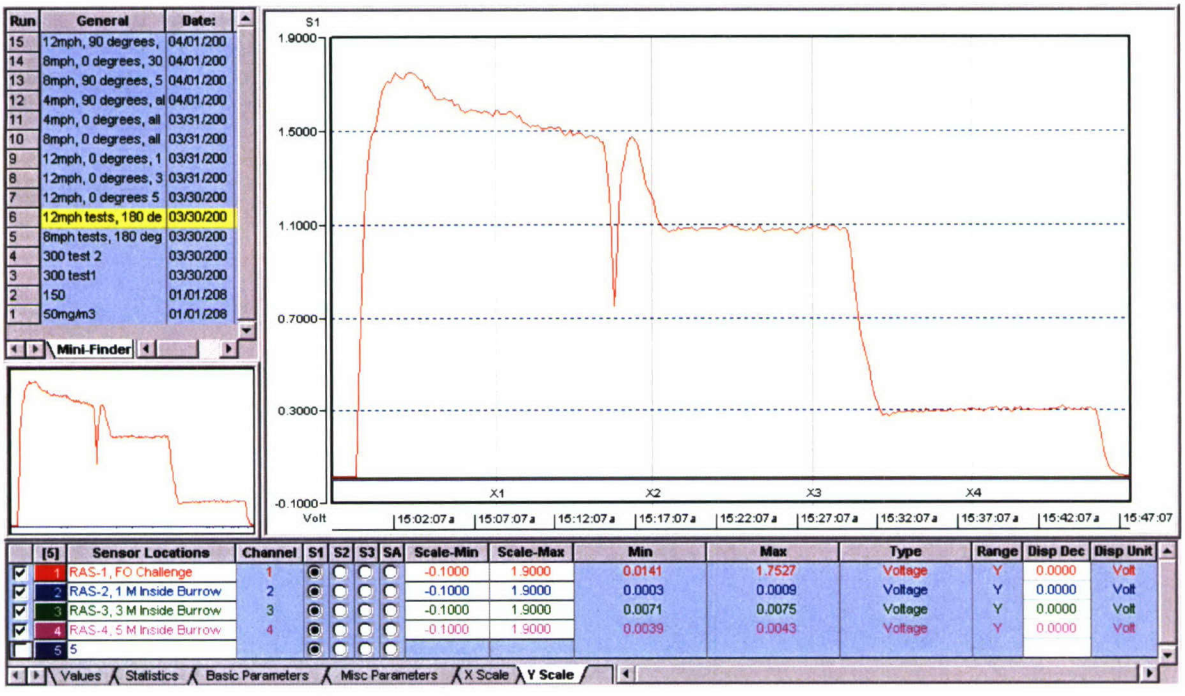
APPENDIX I
FOG OIL CONCENTRATION PROFILE FOR MODEL GOPHER TORTOISE BURROW TESTING, 12 MPH, 180°, 3 CONCENTRATIONS



12 mph 180°	Challenge (mg/m^3)	1 m (mg/m^3)
Mean	51.72	0.01
Min	49.77	0.00
Max	54.26	0.03
Median	51.63	0.01
Std-D	0.85	0.01
Count	64.00	64.00
Mean	164.26	0.03
Min	161.81	0.01
Max	166.93	0.04
Median	164.26	0.03
Std-D	1.04	0.01
Count	70	70.00
Mean	240.85	0.04
Min	226.18	0.01
Max	261.11	0.07
Median	237.18	0.03
Std-D	11.11	0.02
Count	64	64

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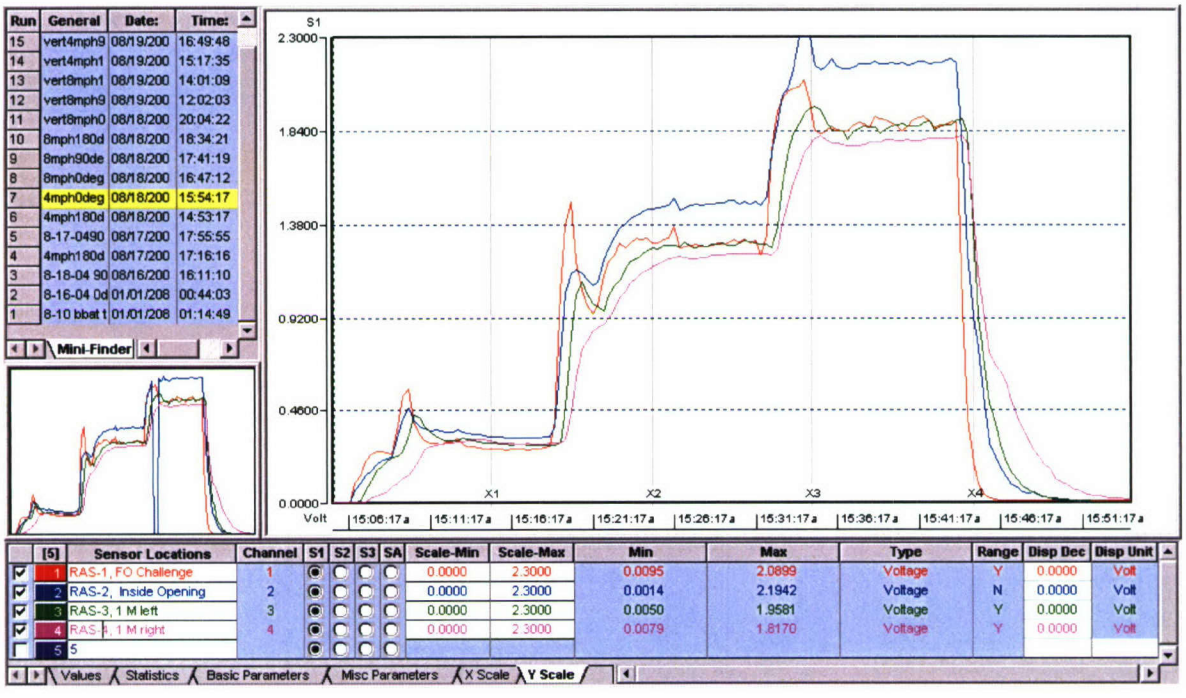
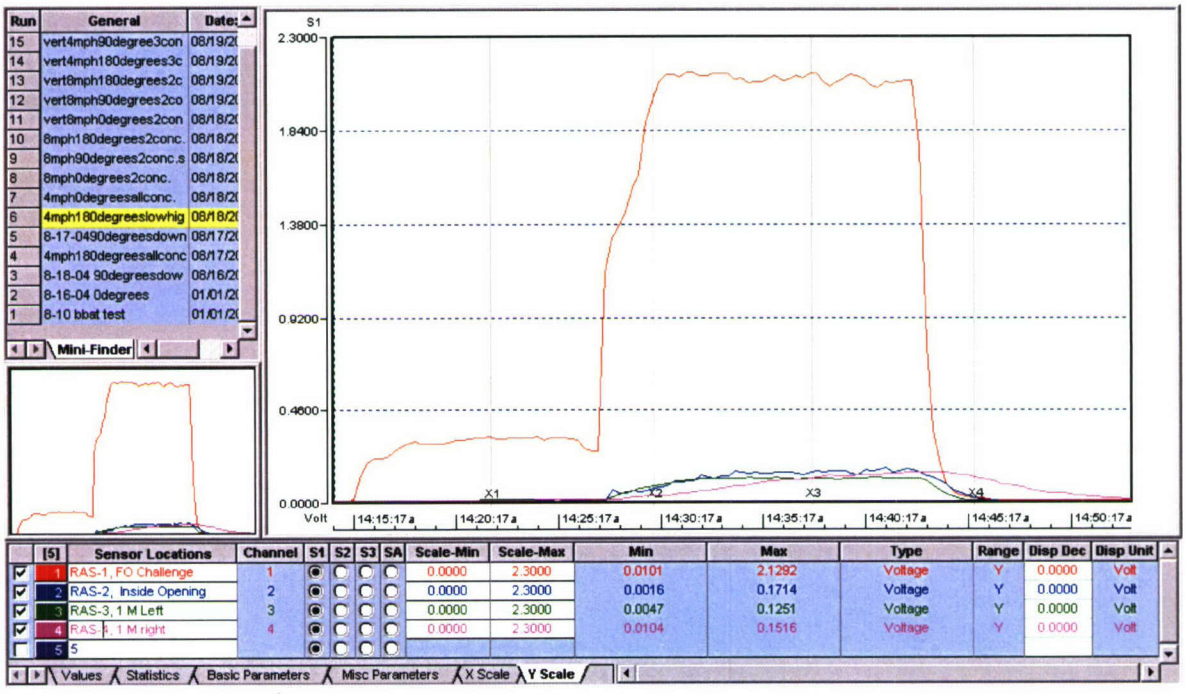
APPENDIX J
FOG OIL CONCENTRATION PROFILE FOR MODEL TREE TRUNK CAVITY TESTING,
4 MPH, 0°, 3 CONCENTRATIONS

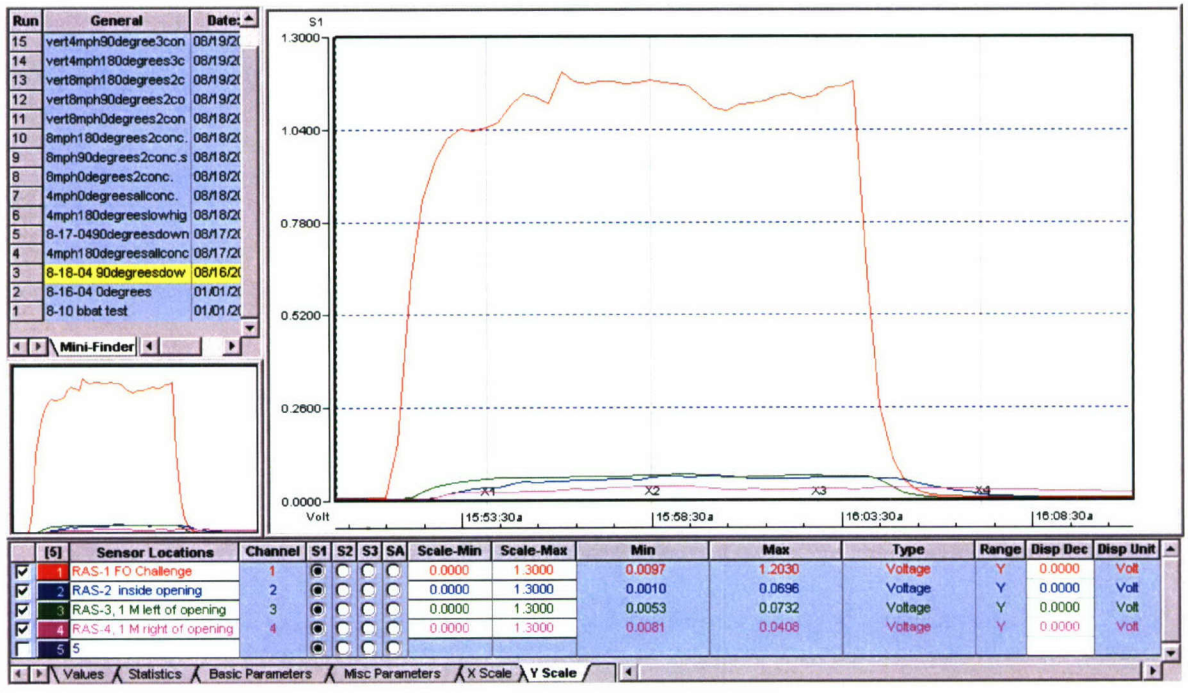


Series (mph)	Parameter	FO Challenge mg/m^3	Measured Fog Oil Concentration			Percent Fog Oil Penetration		
			Inside Entrance mg/m^3	1 m Left mg/m^3	1 m Right mg/m^3	Entrance %	1 m Left %	1 m Right %
	Avg	51.2	53.5	56.9	44.8	104.6	111.1	87.5
	Min	38.5	27.2	19.2	9.0	70.6	70.5	46.9
4	Max	90.2	74.3	82.5	57.9	82.4	110.9	70.2
0°	Std-D	6.5	6.4	8.1	14.1			
	Count	35.0	35.0	35.0	35.0			
	Sample Time (min)	11.7	11.7	11.7	11.7			
	Avg	193.3	212.6	218.0	192.6	110	112.8	99.6
	Min	170.8	178.5	170.0	148.6	104.5	99.5	87.0
4	Max	206.2	222.4	228.9	203.4	107.8	111.0	98.6
0°	Std-D	6.1	10.1	14.3	15.6			
	Count	31.0	31.0	31.0	31.0			
	Sample Time (min)	10.3	10.3	10.3	10.3			
	Avg	282.1	314.2	323.5	288.6	111.4	114.7	102.3
	Min	272.1	298.9	292.8	244.2	109.9	107.6	89.8
4	Max	309.8	318.9	344.2	319.2	102.9	111.1	103.0
0°	Std-D	9.9	3.6	9.6	12.0			
	Count	32.0	32.0	32.0	32.0			
	Sample Time (min)	10.7	10.7	10.7	10.7			

Blank

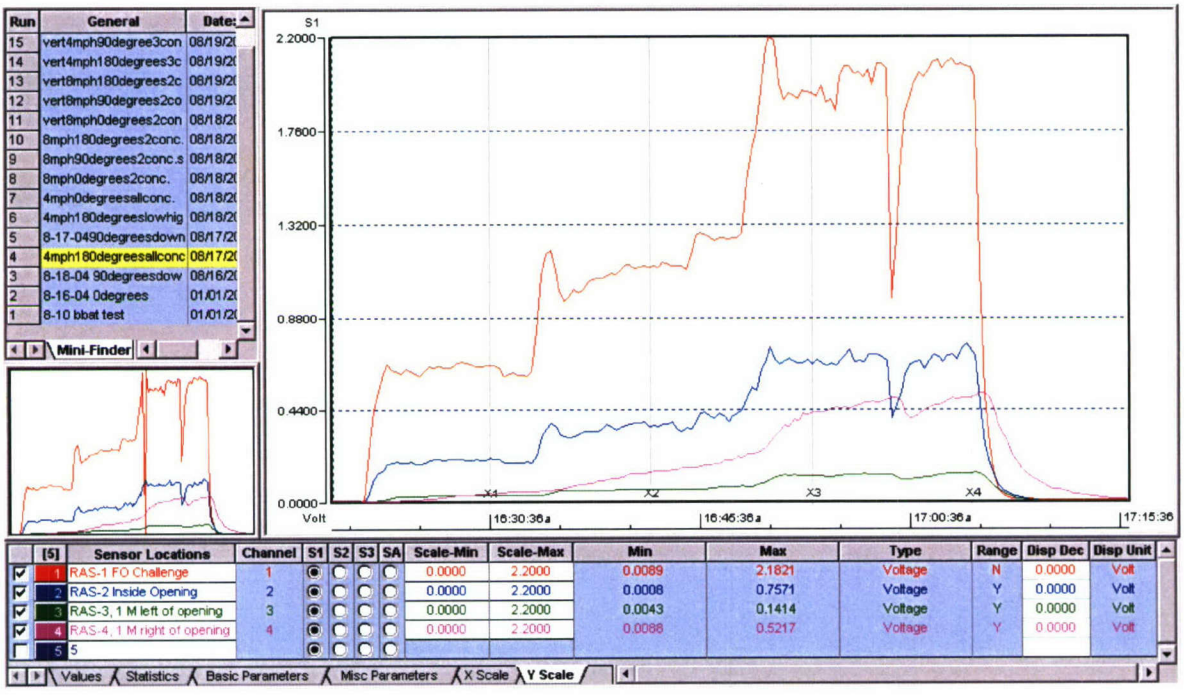
APPENDIX K
FOG OIL CONCENTRATION PROFILE FOR MODEL TREE TRUNK CAVITY TESTING,
4 MPH, 90°, 3 CONCENTRATIONS





Series (mph)	Parameter	FO Challenge (mg/m^3)	Measured Fog Oil Concentration			Percent Fog Oil Penetration		
			Inside Entrance (mg/m^3)	1 m Left (mg/m^3)	1 m Right (mg/m^3)	Entrance (%)	1 m Left (%)	1 m Right (%)
4 90°	Avg	52.3	9.6	11.1	10.0	18.4	21.2	20.1
	Min	44.9	8.6	10.4	9.4	19.1	23.2	21.9
	Max	55.2	10.5	11.3	10.5	19.0	20.5	20.1
	Std-D	2.9	0.4	0.2	0.4			
	Count	30.0	30.0	30.0	30.0			
	Sample Time (min)	10.0	10.0	10.0	10.0			
4 90°	Avg	173.2	16.2	20.0	12.9	9.4	11.5	7.5
	Min	161.0	13.0	19.1	11.7	8.1	11.9	7.3
	Max	181.7	17.6	20.8	14.2	9.7	11.5	7.8
	Std-D	4.7	1.0	0.5	0.7			
	Count	29.0	29.0	29.0	29.0			
	Sample Time (min)	9.7	9.7	9.7	9.7			
4 90°	Avg	310.4	27.5	28.2	23.8	8.8	9.1	7.7
	Min	295.8	18.0	22.8	13.3	6.1	7.7	4.5
	Max	315.5	32.0	29.6	31.2	10.1	9.4	9.9
	Std-D	3.8	3.5	1.5	6.0			
	Count	39.0	39.0	39.0	39.0			
	Sample Time (min)	13.0	13.0	13.0	13.0			

APPENDIX L
FOG OIL CONCENTRATION PROFILE FOR MODEL TREE TRUNK CAVITY TESTING,
4 MPH, 180°, 3 CONCENTRATIONS



Series (mph)	Parameter	FO Challenge (mg/m^3)	Measured Fog Oil Concentration: Inside Entrance (mg/m^3)	1 m Left (mg/m^3)	1 m Right (mg/m^3)	Percent Fog Oil Penetration: Entrance (%)	1 m Left (%)	1 m Right (%)
4 180°	Avg	99.5	35.5	13.9	12.5	35.7	13.9	12.6
	Min	94.9	29.6	10.9	9.1	31.1	11.5	9.6
	Max	104.2	38.0	14.6	16.4	36.5	14.0	15.7
	Std-D	3.0	1.7	0.8	2.6			
	Count	33.0	33.0	33.0	33.0			
	Sample Time (min.)	11.0	11.0	11.0	11.0			
4 180°	Avg	172.3	59.8	19.1	29.2	34.7	11.1	16.9
	Min	146.3	51.9	15.3	16.7	35.5	10.5	11.4
	Max	193.3	69.9	21.6	42.6	36.2	11.2	22.0
	Std-D	13.0	4.7	1.3	7.3			
	Count	43.0	43.0	43.0	43.0			
	Sample Time (min.)	14.3	14.3	14.3	14.3			
4 180°	Avg	299.6	104.6	30.0	76.8	34.9	10.0	25.6
	Min	275.7	97.9	25.2	49.0	35.5	9.2	17.8
	Max	325.7	114.8	32.3	88.6	35.3	9.9	27.2
	Std-D	11.4	3.5	1.4	9.2			
	Count	41.0	41.0	41.0	41.0			
	Sample Time (min.)	13.7	13.7	13.7	13.7			

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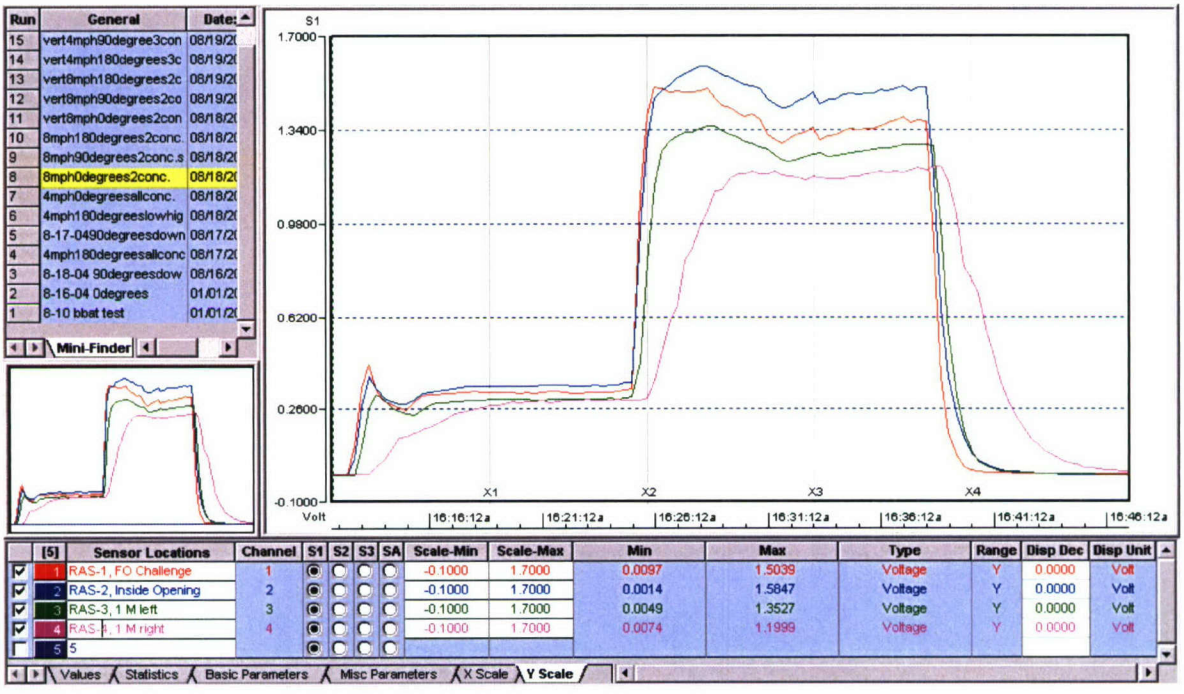
APPENDIX M
FOG OIL CONCENTRATION PROFILE FOR MODEL TREE TRUNK CAVITY TESTING,
8 MPH, 0°, 3 CONCENTRATIONS



Series (mph)	Parameter	FO Challenge (mg/m^3)	Measured Fog Oil Concentration: Inside Entrance (mg/m^3)	1 m Left (mg/m^3)	1 m Right (mg/m^3)	Percent Fog Oil Penetration: Entrance (%)	1 m Left (%)	1 m Right (%)
	Avg	54.3	56.7	57.8	50.0	104.5	106.5	92.1
	Min	41.9	49.9	48.6	34.1	119.0	115.9	81.4
8	Max	57.4	59.2	60.0	54.9	103.1	104.6	95.6
0°	Std-D	2.6	1.8	2.4	6.1			
	Count	30.0	30.0	30.0	30.0			
	Sample Time (min)	10.0	10.0	10.0	10.0			
	Avg	208.4	219.5	223.9	177.3	105.4	107.5	85.1
	Min	194.1	209.2	198.7	66.8	107.8	102.4	34.4
8	Max	225.2	231.9	237.1	196.4	103.0	105.3	87.2
0°	Std-D	9.7	6.1	7.6	33.1			
	Count	37.0	37.0	37.0	37.0			
	Sample Time (min)	12.3	12.3	12.3	12.3			

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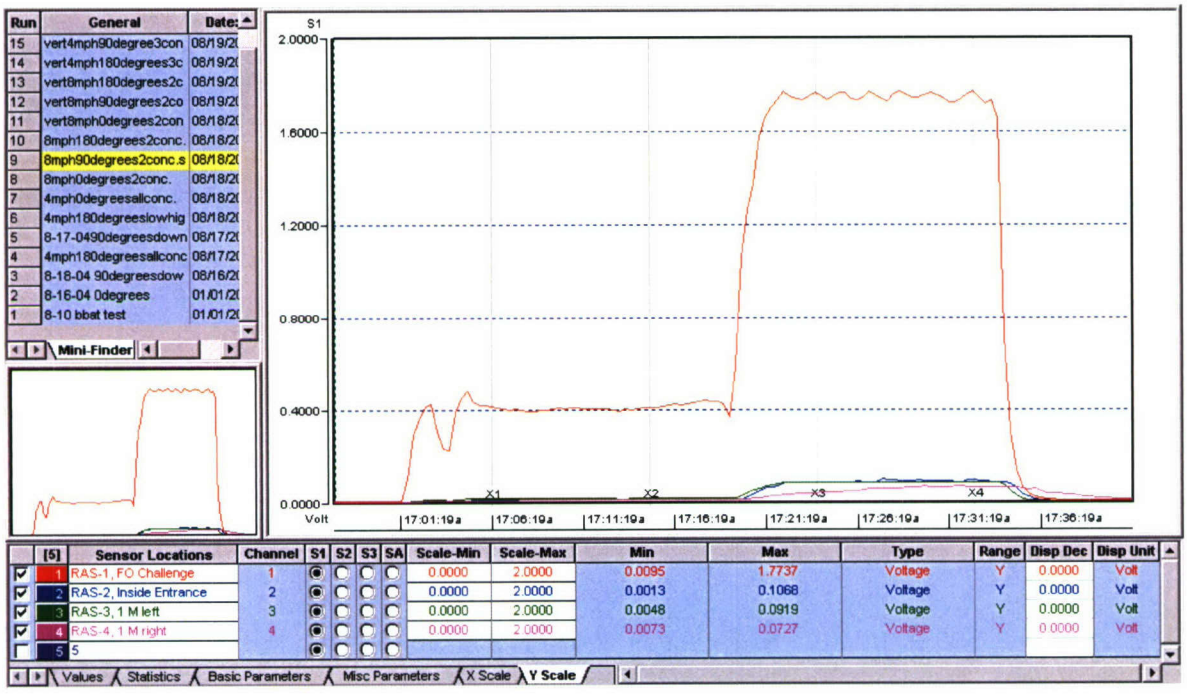
APPENDIX N
FOG OIL CONCENTRATION PROFILE FOR MODEL TREE TRUNK CAVITY TESTING,
8 MPH, 90°, 3 CONCENTRATIONS



Series (mph)	Parameter	FO Challenge (mg/m^3)	Measured Fog Oil Concentration: Inside Entrance (mg/m^3)	1 m Left (mg/m^3)	1 m Right (mg/m^3)	Percent Fog Oil Penetration: Entrance (%)	1 m Left (%)	1 m Right (%)
8 90°	Avg	67.4	10.1	11.8	10.1	15.0	17.5	15.0
	Min	64.9	9.9	11.6	9.6	15.3	17.9	14.8
	Max	71.5	10.5	12.0	10.3	14.7	16.7	14.4
	Std-D	1.8	0.2	0.1	0.2			
	Count	41.0	41.0	41.0	41.0			
	Sample Time (min)	13.7	13.7	13.7	13.7			
8 90°	Avg	260.3	20.9	23.5	17.1	8.0	9.0	6.6
	Min	247.1	18.3	22.5	13.0	7.4	9.1	5.2
	Max	264.1	22.9	24.0	19.2	8.7	9.1	7.3
	Std-D	3.0	0.8	0.3	2.0			
	Count	37.0	37.0	37.0	37.0			
	Sample Time (min)	12.3	12.3	12.3	12.3			

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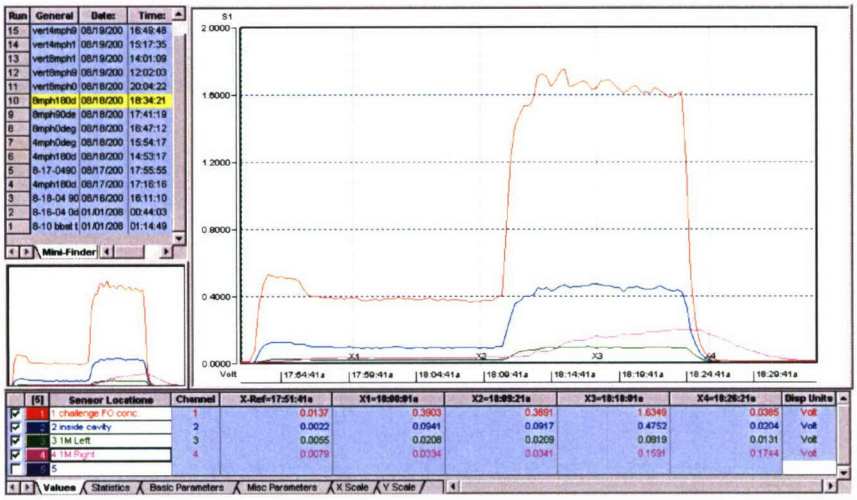
APPENDIX O
FOG OIL CONCENTRATION PROFILE FOR MODEL TREE TRUNK CAVITY TESTING,
8 MPH, 180°, 3 CONCENTRATIONS



Series (mph)	Parameter	FO Challenge (mg/m^3)	Measured Fog Oil Concentration			Percent Fog Oil Penetration		
			Inside Entrance (mg/m^3)	1 m Left (mg/m^3)	1 m Right (mg/m^3)	Entrance (%)	1 m Left (%)	1 m Right (%)
4 180°	Avg	172.3	59.8	19.1	29.2	34.7	11.1	16.9
	Min	146.3	51.9	15.3	16.7	35.5	10.5	11.4
	Max	193.3	69.9	21.6	42.6	36.2	11.2	22.0
	Std-D	13.0	4.7	1.3	7.3			
	Count	43.0	43.0	43.0	43.0			
	Sample Time (min)	14.3	14.3	14.3	14.3			
4 180°	Avg	299.6	104.6	30.0	76.8	34.9	10.0	25.6
	Min	275.7	97.9	25.2	49.0	35.5	9.2	17.8
	Max	325.7	114.8	32.3	88.6	35.3	9.9	27.2
	Std-D	11.4	3.5	1.4	9.2			
	Count	41.0	41.0	41.0	41.0			
	Sample Time (min)	13.7	13.7	13.7	13.7			

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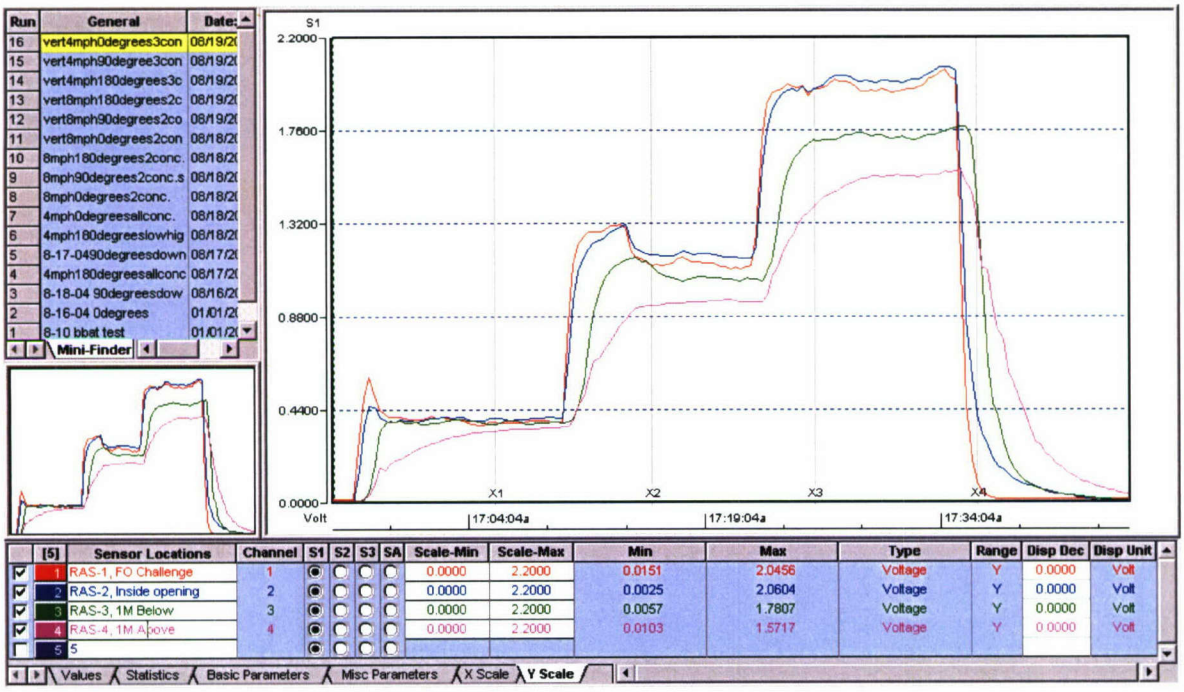
APPENDIX P

FOG OIL CONCENTRATION PROFILE FOR MODEL TREE TRUNK CAVITY, VERTICAL TESTING, 4 MPH, 0°, 3 CONCENTRATIONS



Series (mph)	Parameter	Measured Fog Oil Concentration				Percent Fog Oil Penetration		
		FO Challenge (mg/m^3)	Inside Entrance (mg/m^3)	1 m Below (mg/m^3)	1 m Above (mg/m^3)	Entrance (%)	1 m Below (%)	1 m Above (%)
V 4 0°	Avg	64.2	63.8	73.0	55.9	99.5	113.8	87.1
	Min	60.8	61.8	70.9	32.5	101.5	116.6	53.5
	Max	68.3	65.2	75.1	64.4	95.5	110.0	94.3
	Std-D	1.8	1.0	1.1	9.0			
	Count	35.0	35.0	35.0	35.0			
	Sample Period (min)	11.7	11.7	11.7	11.7			
V 4 0°	Avg	176.9	177.1	190.3	150.5	100.1	107.5	85.0
	Min	167.6	170.9	160.9	113.5	101.9	94.1	67.7
	Max	197.5	193.9	204.6	159.4	98.2	105.5	80.7
	Std-D	10.4	6.7	8.6	13.2			
	Count	31.0	31.0	31.0	31.0			
	Sample Period (min)	10.3	10.3	10.3	10.3			
V 4 0°	Avg	292.5	289.9	297.8	241.6	99.1	101.8	82.6
	Min	285.4	280.7	257.1	194.6	98.4	90.1	68.2
	Max	303.4	299.1	308.1	255.4	98.6	101.5	84.2
	Std-D	4.1	4.8	10.0	16.4			
	Count	34.0	34.0	34.0	34.0			
	Sample Period (min)	11.3	11.3	11.3	11.3			

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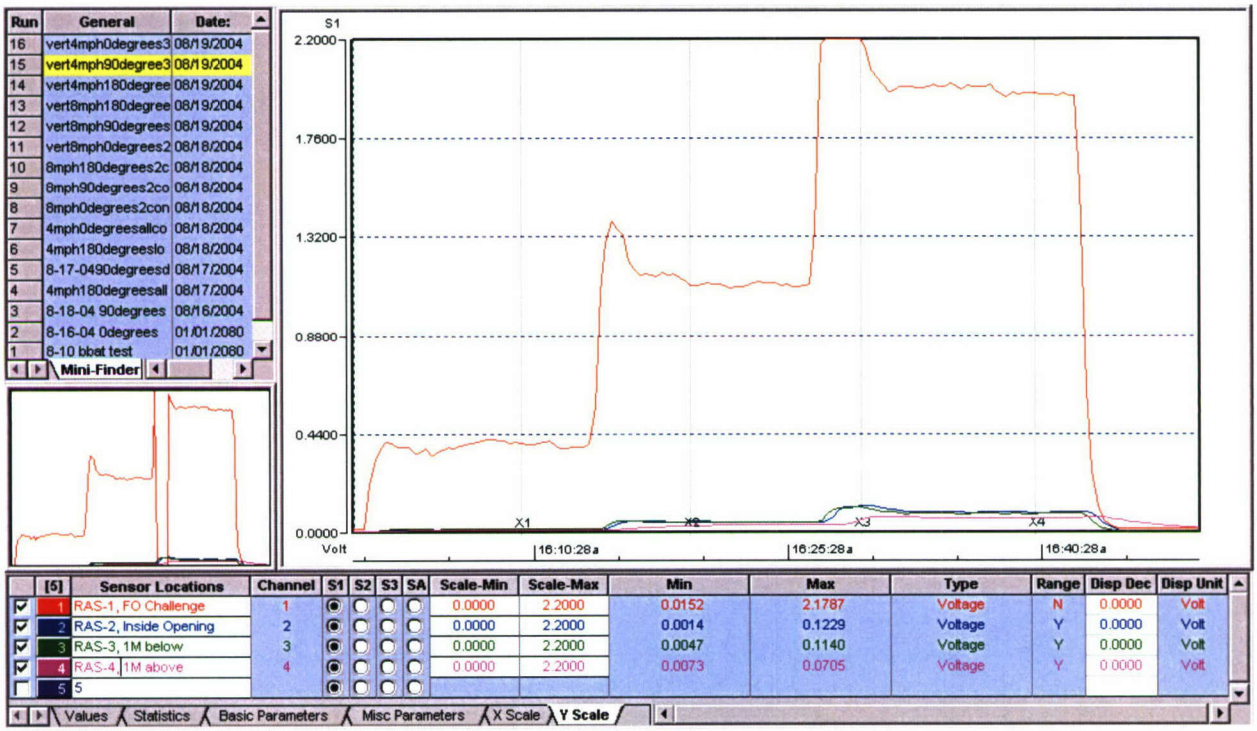
APPENDIX Q
FOG OIL CONCENTRATION PROFILE FOR MODEL TREE TRUNK CAVITY, VERTICAL TESTING, 4 MPH, 90°, 3 CONCENTRATIONS



Series (mph)	Parameter	Measured Fog Oil Concentration				Percent Fog Oil Penetration		
		FO Challenge (mg/m^3)	Inside Entrance (mg/m^3)	1 m Below (mg/m^3)	1 m Above (mg/m^3)	Entrance (%)	1 m Below (%)	1 m Above (%)
V 4 90°	Avg	64.3	9.8	11.3	9.6	15.3	17.5	15.0
	Min	57.3	9.2	11.0	8.9	16.1	19.1	15.6
	Max	68.6	10.1	11.5	10.1	14.7	16.8	14.7
	Std-D	2.6	0.2	0.1	0.3			
	Count	36.0	36.0	36.0	36.0			
	Sample Period (min)	12.0	12.0	12.0	12.0			
V 4 90°	Avg	171.0	14.6	16.4	12.6	8.6	9.6	7.3
	Min	165.7	14.1	15.9	10.3	8.5	9.6	6.2
	Max	199.8	15.4	17.3	13.5	7.7	8.7	6.7
	Std-D	6.4	0.3	0.4	0.9			
	Count	34.0	34.0	34.0	34.0			
	Sample Period (min)	11.3	11.3	11.3	11.3			
V 4 90°	Avg	293.2	20.8	22.9	18.0	7.1	7.8	6.2
	Min	288.4	20.0	22.1	17.7	6.9	7.7	6.1
	Max	297.9	23.2	24.4	18.9	7.8	8.2	6.3
	Std-D	2.7	0.7	0.5	0.2			
	Count	35.0	35.0	35.0	35.0			
	Sample Period (min)	11.7	11.7	11.7	11.7			

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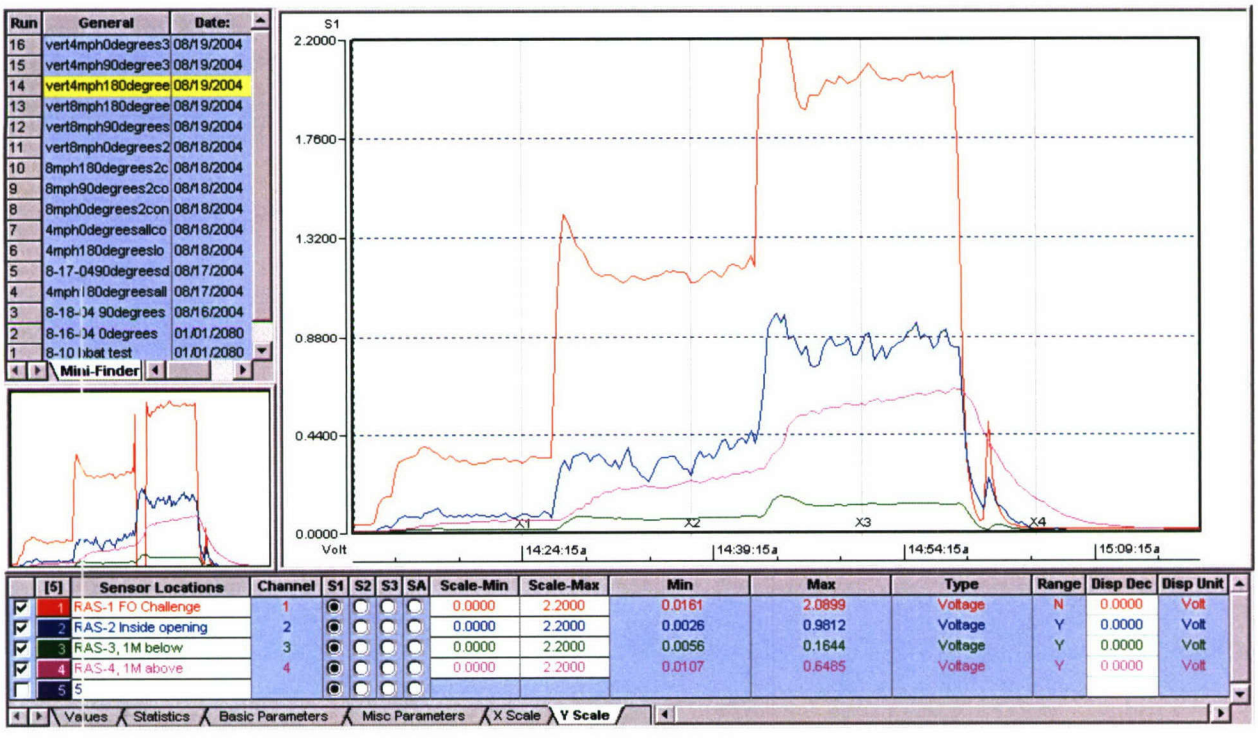
APPENDIX R
FOG OIL CONCENTRATION PROFILE FOR MODEL TREE TRUNK CAVITY, VERTICAL TESTING, 4 MPH, 180° DEGREES, 3 CONCENTRATIONS



Series (mph)	Parameter	Measured Fog Oil Concentration				Percent Fog Oil Penetration		
		FO Challenge (mg/m^3)	Inside Entrance (mg/m^3)	1 m Below (mg/m^3)	1 m Above (mg/m^3)	Entrance (%)	1 m Below (%)	1 m Above (%)
	Avg	56.6	19.5	11.6	15.6	34.4	20.5	27.5
	Min	52.3	17.6	11.4	11.4	33.6	21.9	21.8
V 4	Max	64.1	24.2	12.1	17.4	37.7	18.9	27.1
180°	Std-D	3.0	1.5	0.2	1.5			
	Count	34.0	34.0	34.0	34.0			
	Sample Period (min)	11.3	11.3	11.3	11.3			
	Avg	178.3	55.5	19.7	42.3	31.2	11.0	23.7
	Min	170.1	39.9	18.0	29.0	23.4	10.6	17.1
V	Max	247.0	72.6	21.1	51.9	29.4	8.6	21.0
180°	Std-D	13.3	7.4	0.8	5.3			
	Count	40.0	40.0	40.0	40.0			
	Sample Period (min)	13.3	13.3	13.3	13.3			
	Avg	300.2	127.1	30.1	101.5	42.3	10.0	33.8
	Min	289.2	112.7	29.1	92.3	39.0	10.0	31.9
V 4	Max	309.8	141.4	31.0	110.3	45.6	10.0	35.6
180°	Std-D	4.4	7.1	0.5	4.8			
	Count	35.0	35.0	35.0	35.0			
	Sample Period (min)	11.7	11.7	11.7	11.7			

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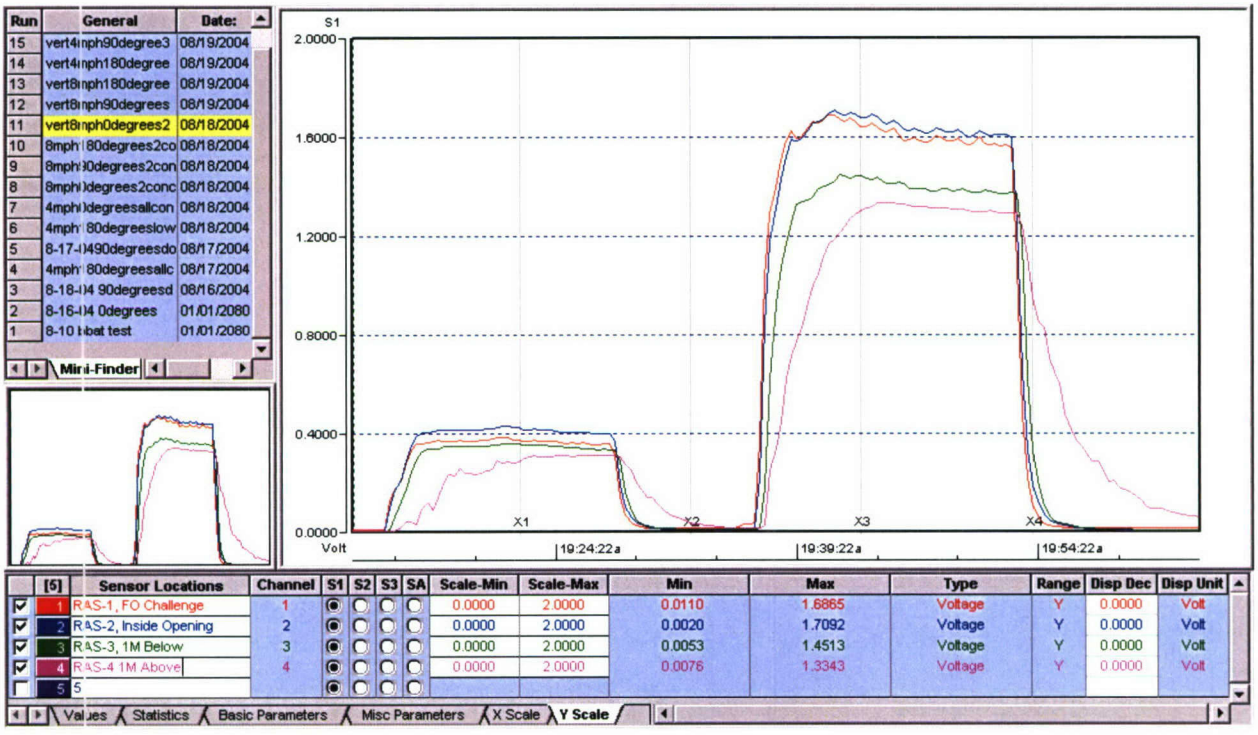
APPENDIX S
FOG OIL CONCENTRATION PROFILE FOR MODEL TREE TRUNK CAVITY, VERTICAL TESTING, 8 MPH, 0°, 2 CONCENTRATIONS



Series (mph)	Parameter	Measured Fog Oil Concentration				Percent Fog Oil Penetration		
		FO Challenge (mg/m^3)	Inside Entrance (mg/m^3)	1 m Below (mg/m^3)	1 m Above (mg/m^3)	Entrance (%)	1 m Below (%)	1 m Above (%)
V 8 0°	Avg	61.0	66.1	66.5	49.8	108.5	109.1	81.7
	Min	53.2	60.3	48.6	22.2	113.4	91.3	41.7
	Max	63.3	68.7	69.5	57.4	108.6	109.8	90.7
	Std-D	1.7	1.6	3.3	10.1			
	Count	37.0	37.0	37.0	37.0			
	Sample Time (min)	12.3	12.3	12.3	12.3			
V 8 0°	Avg	241.1	239.9	244.1	203.1	99.5	101.2	84.2
	Min	233.5	232.0	221.0	121.3	99.4	94.7	51.9
	Max	251.5	249.5	253.7	218.7	99.2	100.9	86.9
	Std-D	5.5	4.9	6.1	25.1			
	Count	42.0	42.0	42.0	42.0			
	Sample Time (min)	14.0	14.0	14.0	14.0			

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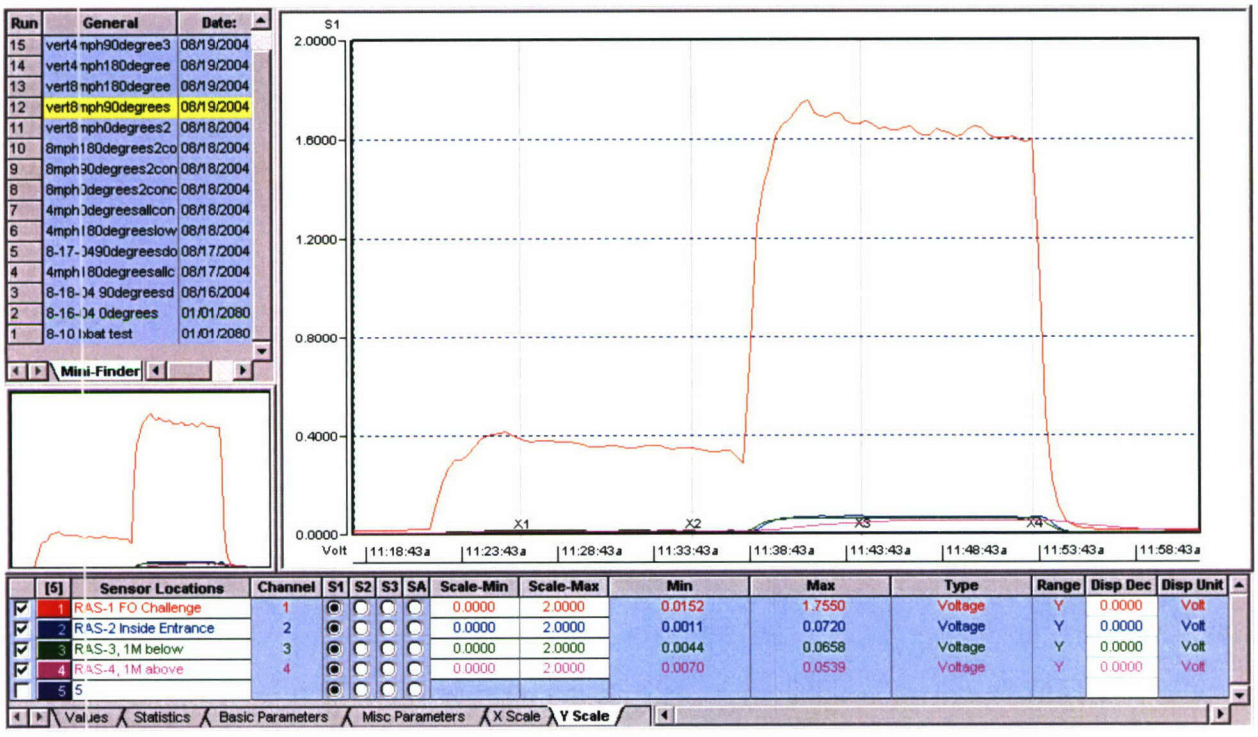
APPENDIX T

FOG OIL CONCENTRATION PROFILE FOR MODEL TREE TRUNK CAVITY, VERTICAL TESTING, 8 MPH, 90°, 2 CONCENTRATIONS



Series (mph)	Parameter	Measured Fog Oil Concentration				Percent Fog Oil Penetration		
		FO Challenge (mg/m^3)	Inside Entrance (mg/m^3)	1 m Below (mg/m^3)	1 m Above (mg/m^3)	Entrance (%)	1 m Below (%)	1 m Above (%)
V 8 90°	Avg	60.1	9.4	10.8	9.7	15.7	17.9	16.1
	Min	52.7	9.1	10.5	9.0	17.4	19.9	17.0
	Max	68.1	9.6	11.0	10.0	14.1	16.1	14.6
	Std-D	3.4	0.1	0.1	0.3			
	Count	43.0	43.0	43.0	43.0			
	Sample Time (min)	14.3	14.3	14.3	14.3			
V 8 90°	Avg	246.2	17.5	19.1	15.2	7.1	7.8	6.2
	Min	237.7	17.0	18.5	11.7	7.1	7.8	4.9
	Max	261.4	18.0	19.6	16.2	6.9	7.5	6.2
	Std-D	5.9	0.2	0.2	1.3			
	Count	38.0	38.0	38.0	38.0			
	Min	12.7	12.7	12.7	12.7			

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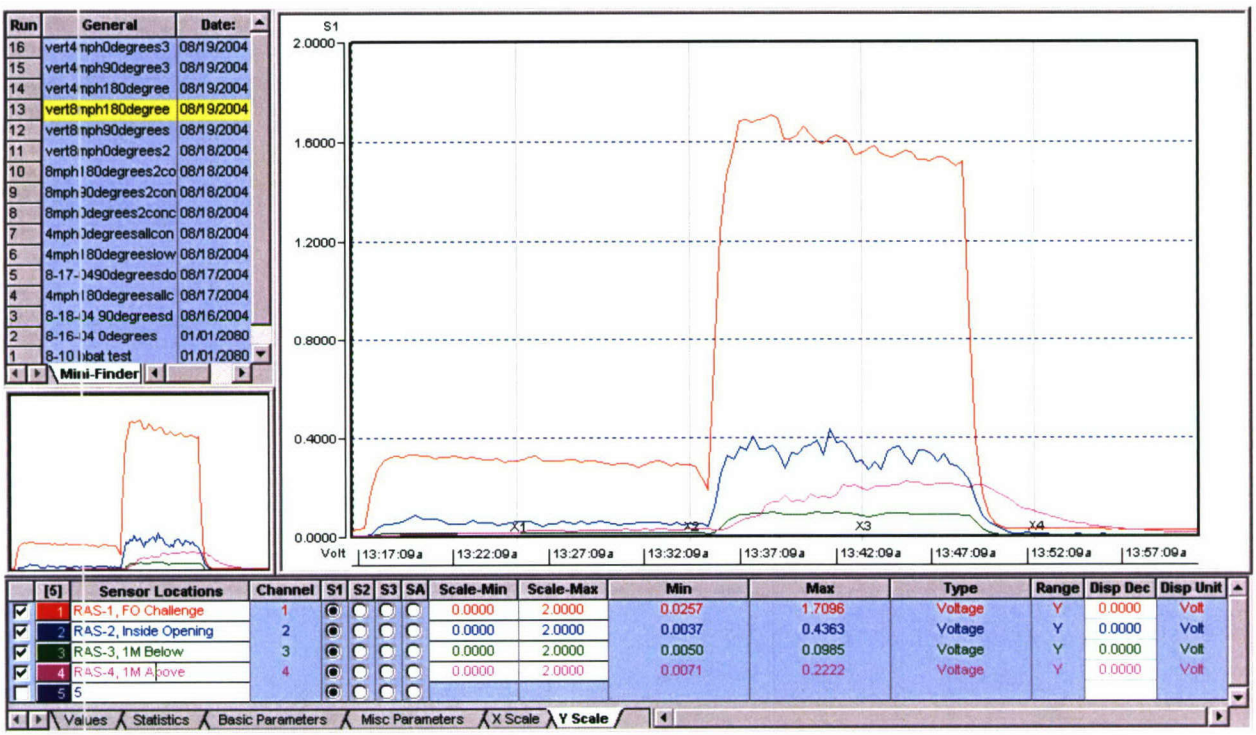
APPENDIX U
FOG OIL CONCENTRATION PROFILE FOR MODEL TREE TRUNK CAVITY, VERTICAL TESTING, 8 MPH, 180°, 2 CONCENTRATIONS



Series (mph)	Parameter	Measured Fog Oil Concentration				Percent Fog Oil Penetration		
		FO Challenge (mg/m^3)	Inside Entrance (mg/m^3)	1 m Below (mg/m^3)	1 m Above (mg/m^3)	Entrance (%)	1 m Below (%)	1 m Above (%)
V 8 180°	Avg.	48.4	15.4	10.4	10.0	31.8	21.5	20.6
	Min	44.4	13.5	10.2	7.8	30.5	23.1	17.7
	Max	52.0	19.8	10.7	11.7	38.1	20.6	22.6
	Std-D	1.9	1.2	0.1	1.2			
	Count	48.0	48.0	48.0	48.0			
	Sample Period (min)	16.0	16.0	16.0	16.0			
V 8 180°	Avg.	233.7	54.8	23.0	34.7	23.4	9.8	14.8
	Min.	220.6	44.0	21.1	18.5	20.0	9.6	8.4
	Max	250.8	68.9	24.2	41.7	27.5	9.7	16.6
	Std-D	8.7	5.8	0.8	6.6			
	Count	35.0	35.0	35.0	35.0			
	Sample Period (min)	11.7	11.7	11.7	11.7			